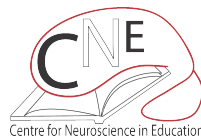


Rhythmic Perception and Entrainment in 5-Year-Old Children.

An Exploration of the Relationship between Temporal Accuracy at Four Isochronous Rates and its Impact on Phonological Awareness and Reading Development.

An investigation into how the structure of simple songs and nursery rhymes could best increase ‘large grain’ phonological awareness skills (rhyme and syllable awareness) in 4 to 5 year old children as part of a classroom based pre-literacy strategy.



This dissertation is submitted for the degree of Doctor of Philosophy

By John P. Verney

Supervisor: Professor Usha Goswami

**The Faculty Of Education
University of Cambridge**

**Homerton College
University of Cambridge**

Preface

Originally the title of the thesis was ‘Entrainment in 5-Year-Old Children: Temporal Accuracy at Four Isochronous Rates and Its impact on Phonological Awareness and Reading Development.....’

After discussion with my PhD examiners it was considered that this title did not fully represent the content of the thesis, nor would it attract the readers who would find the subject matter interesting and of relevance to further study.

However I was reluctant to lose the word ‘entrainment’ from the title because it is used widely in research within the field of neuroscience associated with how brainwave frequencies fall into step with a periodic aural stimulus such as a rhythmic pulse in music or the perception of accents within the speech stream.

Entrainment refers not only to an ability to extract the main accents and stress in music and speech, but also to an ability to maintain a perception of pulse for future use. In speech the pulse or accents might become quite ambiguous at times, but the brain can still assemble them with reference to the entrained beat, thus allowing the listener to predict and react to what will come next. In music the brain can also perceive very small changes to the musical beats or accents that occur whenever we perform music but these, sometimes deliberate, inaccuracies do not affect our ability to synchronise movement such as tapping, drumming, or dancing to the rhythms implicit in the performance.

Rhythmic perception is perhaps a more familiar term than is ‘entrainment’. It is more generally associated with the extraction of the principle beats in a piece of music that allow us to tap and sing along with it, but it also encompasses the rhythmic regularity found in speech accents and stresses. The thesis also explores in some depth the different musical contexts in which the child encounters rhythmic perception, either whilst drumming to music, a metronome or singing with or without a musical harmonised accompaniment.

The modified title is an attempt to place the research into the domains of both an academic readership in experimental psychology and neuroscience and one that is concerned with the teaching of both literacy and music to young children.

Abstract

Phonological awareness is an important component of early literacy and many children struggle to master its key elements, such as the ability to hear syllables and rhymes within the speech stream. The hypothesis explored within this study is that since music and language have parallel auditory perceptual mechanisms then training in rhythmic activities, such as music, could lead to increased understanding of the rhythmic nature required to decode early language and literacy skills. Previous research investigating the relationship between the constructs of music perception and phonological awareness has been promising, but generally inconclusive. Within the study I examine whether there is a link between the temporal processing required to process rhythmic entrainment in both phonological awareness skills and music. The data are interpreted with respect to a theoretical framework linking music and language based on temporal sampling. The ‘temporal sampling theory’ (Goswami, 2011) suggests that the decoding of both language and music is linked to the perception of accent and beat, and that the ability to hear the onset of these accents is critical within a stream of auditory events.

To this end rhythmic entrainment tasks were presented in a range of musical activities including drumming along to music and singing nursery songs and rhymes. The musical and rhythmic activities were given in several different forms, to see which would be most effective in showing the children’s ability to synchronise to a beat. These were all presented at four pulse rates (400 ms, 500 ms, 666 ms, 1000 ms).

Data were collected over a period of 2 years commencing in November 2009. In Study 1 93 4 and 5-year-old children were tested and in Study 2 data were collected from a further 99. In addition to psychometric tests for IQ, Word Recall, teachers from the schools provided information from the children’s Foundation Stage profiles. Phonological awareness skills (syllable and rhyme) were also measured, as was reading development. Overall, children showed greater temporal accuracy (rhythmic entrainment) in keeping time with a musical piece than in keeping time with a metronome. Entrainment accuracy was greatest at the 500 ms rate, the only rate for which entrainment was as accurate with

music and metronome. Individual differences in rhythmic entrainment whilst drumming were not linked to I.Q.

Children were more temporally accurate when singing than in the rhythmic entrainment tasks and temporal accuracy at pulse rates of 500 ms (2 Hz) and 666 ms (1.5 Hz) showed some significant links to rhyme awareness and to reading. Temporal accuracy in singing a rhyming word on time was also greatest at 500 ms, although simply singing along to music did not show a preferred rate. Unexpectedly, temporal accuracy in singing was linked to I.Q., and was not linked independently to syllable and rhyme awareness. However, temporal accuracy in singing at the 500 ms rate was linked to reading.

In Sample 2 of the PhD I report on the results of a seven-week three group matched intervention study of 99 children. The intervention was designed to investigate whether a short intervention of either music or ‘rhythmic speech’ based around the preferred rate of 500ms would lead to improved phonological awareness skills. Group 1 was given a programme of music games and songs, and group 2 was given a matched programme of games and ‘rhythmic speech’, without musical accompaniment or singing, to promote syllable and rhyme awareness. A third group, who received no additional training acted as a control.

The results show that an intervention based on rhythmic structure in either a rhythmic speech form or in musical form can be successful in improving children’s phonological awareness skills. The rhythmic speech programme proved to be a more successful vehicle than the music intervention in improving the phonological skills of this group of 90 children. Both interventions were successful in improving both rhyme and syllable awareness, but the greatest improvements came in the syllable tests.

There was further evidence that an intervention in either rhythmic speech or music would impact on the children’s future reading skills. Both interventions produced significantly higher correlations with a Word Reading test than the control group. There was no evidence to suggest that a musical intervention based on tapping along to a beat was of more benefit than one based on rhythmic speech.

Overall the evidence gathered from the data in this study does suggest that there are direct links between rhythmic awareness, as measured by tapping to an

isochronous beat, and the children's capacity to decode phonological information. The favoured rate at which the brain processes information in both domains, thus linking them together, is at a pulse rate with an Inter Onset Interval set to 500ms.

This study's results could be used to support the development of rhythmic based interventions, in both a rhythmic speech and musical form in support of early literacy skills in 4 and 5 –year –old children.

Acknowledgements

I firstly thank my supervisor Professor Usha Goswami for her academic mentorship. There is no doubt that I would have struggled to achieve the necessary standards and rigour of research without her help and guidance. I feel fortunate to have found, probably the only person, who could have helped me bring this project to fruition after many years of searching for the right road to travel.

I must also thank all the many members within the Centre For Neuroscience and Education who have supported and helped to keep me going over the years. I would particularly like to thank Nichola Daily who has been of enormous help to me in providing administrative support over the long distance between Northumberland and Cambridge.

The whole project was reliant on the co-operation of the seven small schools in Northumberland and they all need a mention:- Amble First, Amble St Cuthbert's, Broomhill, Felton, Red Row, Shilbottle and Swarland. All the headteachers and reception class teachers gave me access to their children without hesitation, and helped me organise the research. The one area of the research that gave me joy, an unusual commodity in academic research, was the children. Working with them and experiencing their delight at the music and rhymes was the reason for my desire to embark on this project. It is so important to foster this joy in education and find ways to make learning exciting and meaningful.

This period of study has been a family affair, and certainly could not have taken place without their support. The long distance between the North and South of England could not have been overcome without the happy accident of my sister moving to Huntingdon. Dorothy and Gerry have provided a second home for my wife and I, especially when I was completing the MEd and needed a base every week. My wife, Margaret, of course has gone through all of the ups and downs associated with trying to complete a PhD when one is a little older than most – and her love and support have been of paramount importance.

The last people to thank are my parents. They won't get to see the final chapter, but I know they would be excited and proud of their son. My mother, an especially gifted lady, believed passionately in education and I dedicate this thesis to her memory.

Declaration of Originality

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text. It is not substantially the same as any that I submitted or will be submitting for a degree or other qualification at this or any other university.

Statement of length

This dissertation is 74286 words in total including headings, but not including , bibliography, tables of contents and list of tables and figures and appendices A – G.

Table of Contents

Chapter 1. Introduction.....	1
1.1 The need for the study within the educational context.....	4
1.2 Government Intervention.....	6
1.3 Need for the Study.....	8
1.4 Practical contributions.....	9
1.5 Research Focus and Design.....	10
Chapter 2. Literature Review.....	16
2.1 Phonological Awareness – the underlying sounds of a language.....	17
2.1.1 Developmental Sequence For Phonological Sensitivity.....	20
2.1.2 Sensitivity to Rhymes.....	22
2.1.3 Sensitivity to Syllables.....	27
2.1.4 Implications for the research paradigm.....	29
2.2 Music Perception and Skill Acquisition in the pre-school child.....	31
2.2.1 The Development of Rhythm Skills in infancy and the pre-school child.....	33
2.2.2 The Development of Pitch in infants and pre-school children.....	35
2.2.3 The development and measurement of musical perception.....	39
The Development of Musical Perception in Infancy.....	41
2.2.4 Perception of Music as a ‘whole’ in the pre-school child.....	43
2.2.5 Implications for the research paradigm.....	48
2.3 Temporal and Rhythmic Processing.....	50
2.3.1 The development of temporal processing in infancy and the pre-school child.....	54
2.3.2 Synchronisation and entrainment to a musical stimuli.....	55
2.3.3 Implications for the research paradigm.....	63
2.4 Parallel Auditory processing in Music and Language.....	65
2.4.1 The interaction of Music and Phonological Skills.....	69
2.4.2 Auditory temporal processing.....	70
2.4.3 Auditory Temporal Processing And Phonological Awareness.....	70
(i) Amplitude Envelope Rise-Time.....	72
(ii) Temporal Sampling Theory.....	74
(iii) Music and Language are linked through ‘song’.....	77
2.4.4 The Peretz and Coulthart Framework (2003).....	79
2.4.5 Implications for the research paradigm.....	82
2.5 A review of studies that have shown that music impacts on literacy development.....	84
(i) Studies exploring music and the causes of developmental dyslexia.....	84
(ii) Studies exploring music to promote literacy development.....	87
Chapter 3 Methods and Procedures.....	94
Aims, hypotheses and research questions in the study.....	94
3.1 Overall Design of the Study.....	96
Study 1 (Year 1).....	97
3.2 Participants.....	97
3.2.1 Participant recruitment.....	98
3.3 Music Measures.....	100
3.3.1 Design of the music tests.....	100
3.3.2 Recording and calibration of the music.....	102
3.3.3 Analysis of the children’s recording.....	104
3.3.4 The Music Tasks.....	108
a) Metronome Task.....	108

b) Beat alignment to music.....	108
c) Beat Alignment - Singing	109
3.4 Experimental Tasks (see appendix E)	111
3.4.1. Standardised I.Q. and Reading Tests	111
3.4.2. Phonological Tasks.....	113
3.5 Procedures in Study 1	114
3.5.1 Familiarisation pre-test music activities.....	114
3.5.2 Testing Environment.....	117
Chapter 4 Results from Study 1	119
4.1. Results of the Entrainment Tests.....	119
(a) Drumming to Metronome and Music	120
(i) Beat alignment in the paced condition.....	120
(ii) Beat alignment in the 'unpaced' condition.....	121
(b) Singing to Music	123
4.2 Study 1 Results from the Rhythmic entrainment in both Drumming and 'Singing in Time' Tasks Compared	125
4.3 Relations between the Music and the Phonological Awareness Tasks	128
Chapter 5 Results from Study 2	131
5.1. Participants and Methodology.....	131
5.1.1 Participants	131
5.1.2 Measures.....	132
5.1.3 The Preliminary Musical activities and Test Environment	132
5.1.4. Participant Details are shown in table 5.1.1	132
5.2 Results for the drumming and singing entrainment tasks in.....	133
Study 2 133	
(a) Drumming Tasks to metronome and music.....	134
(b) Singing to Music	135
(c) Rhythmic entrainment in both Drumming and 'Singing in Time' Compared	136
5.3 Relationships between Beat Alignment and Phonological Awareness tasks in Study 2 138	
i) Correlations between Drumming Tasks and Phonological Awareness Tasks	139
ii) Correlations between Singing Tasks and Phonological Awareness Tasks....	140
Chapter 6 Study Comparisons.....	142
6.1 Beat alignment - Studies 1 and 2 Tasks Compared	142
(a) Study comparisons in the Drumming tasks	142
(i) Drumming to metronome tasks	142
ii) Drumming to Music Tasks.....	143
(b) Study Comparison in the Singing Tasks	145
(i) Singing in Time Tasks	145
(ii) Singing the Rhyme Tasks-Music.....	146
(iii) Singing the Rhyme Tasks+Music.....	147
6.2 Rhythmic entrainment in both Drumming and Singing in Time.....	149
Studies 1 and 2 Tasks Compared	149
6.3 Study Comparisons in the Psychometric Tests	151
6.3.1 Psychometric Measures compared in Studies 1 and 2.....	151
6.3.2 Phonological Awareness Measures compared in Studies 1 and 2	152
6.4 Relationships between Beat Alignment and Phonological Awareness tasks. Studies 1 and 2 Tasks Compared	153
(i) Drumming Tasks.....	153
ii) Singing Tasks.....	155

Chapter 7	A circular statistical analysis of the entrainment to drumming tasks in the full study	159
7.1.	Circular Statistics	159
7.2	Results of the beat alignment tasks compared in both linear and circular statistical analyses.....	166
a)	Full study data analysis using a linear statistical method	166
Chapter 8	Study 2 - The Intervention programme.....	174
8.1	Participants and Methodology.....	174
8.1.1	Pre-tests and Post-tests Intervention timetable	175
8.2	The Music Intervention. (For full lesson notes see appendix G)	176
8.2.1	Musical activities for Syllable Training	177
8.2.2	Musical activities for Rhyme training	178
a)	Familiar Songs.....	178
b)	New songs.....	179
c)	Flash card games.....	181
8.3	The Rhythmic Speech Intervention.....	182
Chapter 9	Results from the matched group intervention	184
9.1	The Matched Group Intervention	184
a)	Pre-test analysis comparing groups in the psychometric measures	184
b)	Pre-test analysis comparing groups in the drumming tasks.....	185
c)	Pre-test analysis comparing groups in the singing tasks	185
9.2	Analysis of the group performance in the Phonological Awareness tasks between pre and post-tests	188
(a)	Analysis of the Rhyme pre-and post-test results.....	188
(b)	Analysis of the Syllable pre-and post-test results	191
(c)	Analysis of the effects of all the Phonological Awareness Tasks in the pre and post-tests.	193
9.3.	Impact of intervention on concurrent reading skills.....	196
9.4	The analysis of further music tests on group performance.....	196
Chapter 10	Discussion.....	200
10.1	Research Question 1	202
10.1.1	An Analysis of the children's Metrical Perception	203
a)	Accuracy of metrical perception in the drumming tasks in the Full Study	207
b)	Accuracy of metrical perception in the singing tasks in the Full Study (See appendix H)	211
10.2	Research Question 2	215
10.3	Research Question 3	218
10.4	Research Question 4	220
10.5	Research question 5.....	224
10.6	Research Question 6	227
10.7	Research Question 7	232
11	Conclusions – Future Research.....	234
REFERENCES		237

Appendices

A	Ethical Consent Approval	1
B	Letters to parents and consent Forms.....	2
C	Bongo Phonics CD and track order	5
D	Tune Set 1	6
	Marching Through the Jungle	
	It's Nursery Music Day	
	The Soldier's Song	
	Pretty Coloured Snake	
	Tune Set 2	10
	Rover Had A rag	
	The Race Song	
	Ladybird	
	Fly A Kite	
	Post test tunes.....	14
	Tracy and Thomas	
	Bear in the wood	
E	Psychometric and Phonological Tasks	16
	WPPSI Information and Picture Tests	
	BAS (British Ability Scales 11) Elliot. C. D (1996)	
	Word Test Recall Test From Working Memory Test Battery for	
	Children - Pickering and Gathercole (2001)	
	Foundation Stage Profile	
	Picture Syllable Test (D James 2003)	
	Oral Syllable Test (after Treiman & Zukowski 1991)	
	Picture Rhyme Test (D James 2003)	
	Oral Rhyme Test (Phab)	
F	Bongo Phonics Children's Workbook	26
Ga	Lesson Notes Music Programme	30
Gb	Lesson Notes Rhythmic Speech Programme.....	35
H	Results for the Drumming and Singing Entrainment Tasks	
	in the Full Study	40

List of Tables

Table 1.5	Rhythmic Perception and Entrainment in 5-Year-Old Children. Research Focus and Design	15
Table 2.1.	Glossary of Terms Phonological Awareness	16
<i>Figure 2.1</i>	<i>A brief explanation of terms for phonological awareness (P.A)</i>	19
<i>Figure 2.2</i>	<i>Sequence of Acquisition of PA from Zeigler and Goswami 2005</i>	20
Table 2.1.2	<i>Phonological sensitivity Skills in Developmental Sequence</i>	27
Table 2.2.1	<i>Musical Definitions</i>	31
Table 2.2.2	<i>Gooding and Standley (2011) Characteristics of the pre-school child's musical development</i>	34
Table 2.2.3	<i>Table 4 Rhythm Skills – progression from infancy to year 5 in Gooding and Standley (2011)</i>	36
Table 2.2.4	<i>Table 3. Pitch progression from infancy to year 5 in Gooding and Standley (2011)</i>	35
<i>Figure 2.2.1</i>	<i>The Developmental Spiral (Swanwick & Tillman 1986)</i>	41
<i>Figure 2.2.2</i>	<i>Twinkle Twinkle - Groupings and phrases</i>	47
Table 2.3.1	<i>Five Temporal processing Principles (Drake & Bertrand 2003)</i>	50
Table 2.3.2	<i>Grouping and Metrical structures – London 2012</i>	53
<i>Figure 2.3.1</i>	<i>Core Rhythmic side-drum pattern in Ravel's Bolero</i>	56
<i>Figure 2.3.2</i>	<i>A statistical analysis (both linear and circular) of a performance showing deviation and entrainment to a beat. (Clayton 2012)</i>	58
<i>Figure 2.4.1</i>	<i>(The OPERA Hypothesis Patel 2011</i>	68
<i>Figure 2.4.2.</i>	<i>A schematic depiction of wave forms showing slow and fast rise-time stimuli</i>	71
<i>Figure 2.4.3</i>	<i>Representations of waveforms in a Nursery rhyme phrase in music and speech</i>	73
<i>Figure 2.4.4.</i>	<i>A schematic depiction of wave forms showing slow and fast rise-time using musical instruments as stimuli instrument</i>	74
<i>Figure 2.4.5</i>	<i>Mickey Mouse's house- strong and weak accents</i>	77
<i>Figure 2.4.6</i>	<i>An adapted modular model of music processing (Welch, 2005) of Peretz and Coltheart (2003)</i>	80
<i>Figure 2.4.7</i>	<i>An adapted modular model of music processing (Goswami 2009) of Peretz and Coltheart (2003)</i>	80
<i>Figure 2.5.1.</i>	<i>Musical example from the Huss et al study. 2011. 'Music, rhythm, rise-time perception and developmental dyslexia: Perception of musical meter predicts reading and phonology'</i>	85
Table 3.1.1	<i>Gantt Chart for study timeline</i>	96
Table 3.1.2	<i>Ofsted and 'On-entry' data for the 6 participating schools in Study 1</i>	97
<i>Figure 3.2.1.</i>	<i>Simple Harmonic progressions in Music tests</i>	101
<i>Figure 3.2.2</i>	<i>This diagram shows a registration track and the recording out of synchronization before re- recalibration</i>	104

<i>Figure 3.2.3</i>	<i>This diagram shows a registration track and the recording synchronized – any deviations can now be measured</i>	104
<i>Figure 3.2.4</i>	<i>This diagram shows the child playing multiple taps within the IOI – no score can be given.</i>	105
<i>Figure 3.2.5.</i>	<i>Method of recording accuracy of children’s performance in Audacity</i>	105
<i>Figure 3.2.6</i>	<i>Measurement of synchronisation in a song recorded in Audacity. The data were collected from the consonant before the vowel sound</i>	106
<i>Figure 3.2.7</i>	<i>This diagram shows how a child can both anticipate and follow the beat within a tapping task</i>	107
Table 3.2.1	<i>Schematic overview of the different music and songs in Study 1</i>	110
Table 3.3.1	<i>Foundation Stage Profile (DfES 2003)</i>	113
Table 3.4.1	<i>Musical activities used in the familiarisation pre-test sessions</i>	116
<i>Figure 3.4.1.</i>	<i>Hello Pat The Panda</i>	116
<i>Figure 3.4.2</i>	<i>Mickey The Mouse</i>	116
<i>Figure 3.4.3</i>	<i>Art work from Bongo Phonics Book</i>	117
<i>Figure 3.4.4</i>	<i>Child Playing the bongos</i>	117
<i>Figure 3.4.5</i>	<i>Child taking part in the Singing tests</i>	117
Table 3.4.2	<i>Study 1 Timetable commencing January 2009</i>	118
Table 4.1.1	<i>Participant Details in Study 1</i>	119
Table 4.1.2..	<i>Beat alignment in the ‘paced’ condition (mean in ms) in the rhythmic entrainment tasks, with median in parentheses and standard deviations and total N in square brackets</i>	122
Table 4.1.3.	<i>Beat accuracy (mean in ms) by rhythmic entrainment task in the ‘paced’ and ‘unpaced’ conditions with standard deviations (italics) and total N in square brackets</i>	122
Table 4.1.4.	<i>Beat accuracy (mean in ms) by singing task, with median in parentheses and standard deviations and total N in square brackets</i>	124
Table 4.2.1.	<i>Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q</i>	127
Table 4.3.1.	<i>Pearson’s Partial Correlations between Rhythmic Entrainment and Phonological Awareness, controlling for I.Q. (all Phonological Awareness scores = percentages)</i>	128
Table 4.3.2.	<i>Pearson’s Partial Correlations between Singing Tasks and Phonological Awareness, controlling for I.Q. (all Phonological Awareness Scores = percentages)</i>	129
Table 5.1.1	<i>Participant details in Study 2</i>	132
Table 5.2.1	<i>Beat accuracy (mean in ms) by rhythmic entrainment drumming task, with median in parentheses and standard deviations and</i>	133

	<i>total N in square brackets.</i>	
Table 5.2.2	<i>Beat accuracy (mean in ms) by singing task, with median in parentheses and standard deviations and total N in square brackets</i>	134
Table 5.2.3	<i>Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q</i>	137
Table 5.3.1	<i>Pearson's Partial Correlations between Rhythmic Entrainment and Phonological Awareness, controlling for I.Q.(all Phonological Awareness Scores = percentages</i>	139
Table 5.3.2	<i>Pearson's Partial Correlations between Singing Tasks and Phonological Awareness, controlling for I.Q. (all Phonological Awareness scores = percentages)</i>	140
Table 6.1.1	<i>Drumming to Metronome Tasks Study Comparisons</i>	143
Figure 6.1.1	<i>Studies 1 and 2 compared in the Metronome drumming tasks</i>	143
Figure 6.1.2	<i>Drumming to Music Tasks Study Comparisons</i>	144
Table 6.1.2	<i>Drumming to Music Tasks Study Comparisons</i>	144
Figure 6.1.3	<i>Studies 1 and 2 compared Singing in Time tasks</i>	145
Table 6.1.3	<i>Studies 1 and 2 compared Singing in Time tasks</i>	146
Figure 6.1.4	<i>Phase 1 and 2 studies Singing the Rhyme - Music Tasks</i>	146
Table 6.1.4	<i>Phase 1 and 2 studies Singing the Rhyme - Music Tasks</i>	147
Figure 6.1.5	<i>Phase 1 and 2 studies Singing the Rhyme + Music Tasks</i>	147
Table 6.1.5	<i>Phase 1 and 2 studies Singing the Rhyme + Music Tasks</i>	148
Table 6.2.1	<i>Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q – comparing Study 1 and 2 data.</i>	149
Table 6.2.2	<i>Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q – in the combined studies (Full Study)</i>	150
Figure 6.3.1	<i>Phase 1 and 2 studies Psychometric measures</i>	151
Table 6.3.1	<i>Phase 1 and 2 studies Psychometric measures</i>	151
Figure 6.3.2	<i>Phase 1 and 2 studies Phonological Awareness Measures</i>	152
Table 6.3.2	<i>Phase 1 and 2 studies Phonological Awareness Measures</i>	153
Table 6.4.1	<i>Pearson's Partial Correlations between Rhythmic Entrainment in the drumming tasks and Phonological Awareness, controlling for I.Q comparing Studies 1 and 2 (all Phonological Awareness Scores = percentages</i>	154
Table 6.4.2	<i>Pearson's Partial Correlations between Rhythmic Entrainment in the Drumming Tasks and Phonological Awareness, controlling for I.Q in the Full Study</i>	154

Table 6.4.3	<i>Pearson's Partial Correlations between Rhythmic Entrainment in the Singing Tasks and Phonological Awareness, controlling for I.Q in Studies 1 and 2</i>	155
Table 6.4.4	<i>Pearson's Partial Correlations between Rhythmic Entrainment in the Singing Tasks and Phonological Awareness, controlling for I.Q in the Full Study</i>	156
Table 6.4.5	<i>Pearson's Partial Correlations between Rhythmic Entrainment and the BAS word reading test controlling for I.Q in the Full Study</i>	157
Table 7.1.1.	<i>The table shows the change of score when the mean score is calculated from the data taking into account whether the beat is anticipated or delayed (+ and -) Scores are calculated from a trial of 16 beats</i>	161
Figure 7.1.1	<i>A circular statistical diagram showing a positive and negative response time of 100ms in a 400ms trial is converted to 900 before and after the beat (X)</i>	163
Figure 7.1.2	<i>A linear representation of a circular statistical phase analysis showing the participants performance in relation to zero over 16 data points.</i>	164
Figure 7.1.3	<i>A circular statistical analysis showing the linear data below on a circle. The dots represent points 1 and 16 shown in the linear diagram.</i>	165
Table 7.2.1. .	<i>Comparisons between phase accuracy tasks in the full study (mean in ms) drumming tasks, with standard deviations and total N in square brackets</i>	167
Figure 7.2.1	<i>Full Study drumming data using linear methods</i>	168
Figure 7.2.2	<i>Full Study drumming data Measurement in phase across participants π rad</i>	169
Table 7.2.2	<i>Mean Vector Rate for Full study Metronome and Music Drumming Tasks . (S.D in italics)</i>	169
Figure 7.2.3.	<i>Shows the analysis presented in Table 7.2.1 and Figure 7.2.2 in a circular statistical representation and clearly shows the accuracy of the children's performance in both the 500ms Drumming Tasks</i>	170
Figure 7.2.4.	<i>Linear representation of the circular statistical Analysis of the Metronome and Music Tasks at 400ms</i>	171
Figure 7.2.5.	<i>Linear representation of the circular statistical Analysis of the Metronome and Music Tasks at 500ms</i>	171
Figure 7.2.6.	<i>Linear representation of the circular statistical Analysis of the Metronome and Music Tasks at 666ms</i>	172
Figure 7.2.7.	<i>Linear representation of the circular statistical Analysis of the Metronome and Music Tasks at 1000ms</i>	172
Table 8.1.1.	<i>Numbers of children in each of the three groups in Study 2 of PhD study.</i>	175
Table 8.1.2	<i>Study 2 Timetable commencing November 2010</i>	176
Figure 8.2.1	<i>Music Intervention Training Songs</i>	180

Table 8.2.1	<i>Comparing the Rhythmic Speech and Music Interventions Lesson Time Table</i>	182
Table 9.1.1	<i>Participant details in the matched groups</i>	184
Table 9.1.2	<i>Beat accuracy (mean in ms) by rhythmic entrainment task, based on pre-test mean scores of drumming to both metronome and music combined.</i>	185
Table 9.1.3	<i>Beat accuracy (mean in ms) by rhythmic entrainment task, based on the pre-test mean scores of the Singing in Time and + and – Music tasks combined</i>	186
Table 9.2.1	<i>Phonological Awareness by Group Pre and Post-test mean scores</i>	187
Figure 9.2.1.	<i>Time* Group interaction in the Combined Rhyme Tasks</i>	189
Figure 9.2.2.	<i>Time* Group interaction in the Oral Rhyme Task</i>	190
Figure 9.2.3.	<i>Time* Group interaction in the Picture Rhyme Tasks</i>	191
Figure 9.2.4.	<i>Time* Group interaction in the Combined Syllable Tasks</i>	192
Figure 9.2.5.	<i>Time* Group interaction in both the Oral and Picture Syllable Tasks</i>	193
Figure 9.2.6.	<i>Task* Time interaction in the Phonological Measures</i>	194
Figure 9.2.7.	<i>Time *Group interaction in all the Phonological Measures</i>	195
Table 9.3.1.	<i>Pearson's Partial Correlations between Phonological Awareness Post test results and reading, controlling for I.Q for the matched groups</i>	196
Table 9.4.1	<i>Matched Group Drumming Pre and Post-test mean scores</i>	197
Table 9.4.2	<i>Schematic overview of the different music and songs used in the Post-tests</i>	197
Table 10.1.1	<i>Music Composed for this study by Genre</i>	205
Figures 10.1.1	<i>General trends in the paced and 'unpaced' drumming tasks in Phase 1</i>	205
Figure 10.1.2	<i>Drumming to music and metronome Full Study results</i>	207
Figure 10.1.3	<i>An analysis of the accuracy of singing, using 'gross error' synchronisation scores</i>	212
Figure 10.1.4	<i>A comparison of the Singing in Time data – comparing the effect of a gross error score with a score that reflects whether synchronisation is anticipated or delayed</i>	213

Chapter 1. Introduction

This PhD study has been developed in a series of stages over a period of 20 years. Indeed some of the songs had their genesis in the early period of my role as a teacher/advisor of music working with young children in Northumberland Nursery and First schools¹ which commenced in 1991. Prior to this period I had worked both as a classroom and instrumental teacher with children from the ages of 6 to 18.

Because of my training as a musician in a conservatoire of music, my experience as a music teacher and my work as an instrumentalist and conductor, it is not surprising that the initial focus of my early research would be the musical experience of children and how training at an early stage could impact on both their musical performance and their creative development (Verney 1991). However in the latter part of my career in music education I became increasingly aware of the potential for music to enliven and then improve learning in other areas of the curriculum. Indeed it seemed to be able to provide opportunities in a pre-school setting for learning to begin by developing communication channels between the carers and the children, many of whom had very poor communication and language skills. In 2000 a group of Early Year practitioners:- two speech and language therapists, an educational psychologist, an early years advisory teacher and myself joined together to devise a programme of study and assessment for pre-school children who were referred to the Northumberland Speech and Language Service. These children came from nursery schools in the South East of Northumberland, an area of high and persistent unemployment with low educational expectations. The area is also characterised by a very strong local dialect with unusual words and sentence construction. The prosody within the dialect is also quite extreme. Vowel sounds can be elongated and reversed

¹ A First School is part of a three-tier system of education, which is now very uncommon in England, but still occurs in rural areas where travel to larger urban areas is thought to be appropriate only for older children. The First school normally consists of a Nursery group (<3 yr-old children), a Reception

from those found in usual English.² Indeed words that often have one syllable in standard English will have two. ('Home' will become 'hou-em'). When the children enter into school they will experience language from the teaching staff that is very different from that which they encounter at home, particularly from their grandparents. Communication is therefore further hampered.

Teachers had identified that as many as 30 – 50% of the children were considerably below their chronological age in speech and communication skills and needed additional support before they could access even the most basic curriculum. The Speech and Language Service could not cope with these numbers and so it was felt that a short programme of increased phonological awareness skills delivered in the classroom might reduce the large numbers, and then children with the greatest needs could be targeted by additional professional help.

As part of this programme I formulated a series of lessons for children that concentrated on the rhythmic nature of the words in songs and simple musical patterns. The result of this venture was a toolkit for training and assessment in Phonological Awareness called 'Sounds Great' (Lumsden, 2007). It included games to facilitate the core aspects of Phonological awareness that were appropriate to 3 and 4 year-old children.

- 1 *Non-speech sounds – tigers go 'grrrrr'*
- 2 *Listening to and repeating letter sounds – man starts with 'm'*
- 3 *Syllable segmentation – tig-er (has two claps)*
- 4 *Syllable blending to produce compound sounds – fire-man.*
- 5 *Syllable deletion – take away 'fire' and you are left with 'man'*
- 6 *Onset blending – 'd' + 'og' = dog*
- 7 *Rhyming*

Because the intervention included both speech and music the teachers involved in the programme felt that the dual approach seemed to help many more children to improve both their social and communication skills than if the intervention had been purely speech based. It allowed the teachers to embark on age appropriate teaching of early literacy skills in the Reception³ classes in accordance with the English National Curriculum. Even though I

²Card: Cold / Chorch: Church / Claes: Clothes /Clag: Stick / Clarts: Dirt or mud / Clivvor: Clever
Cloot: A cloth eg a dish cloot, or to clout. / Coo: A cow / Craa: Crow (examples from a 'Geordie'
Dictionary - 2009)

³ Children enter into the Reception class in the year of their 5th birthday.

devised an assessment protocol within the programme no effort was made to analyse the data and so no empirical results were obtained.

This research topic came from a desire to explore the reasons for the perceived success of the music within the programme, and a desire to be able to give early years teachers and their pupils further reasons to maintain a musical environment in their classrooms, and be able to understand why it was important, not only to enjoy their existing musical activities that helped to galvanise the children into a positive learning environment, but also to participate in musical activities which would actually enable transfer of information from music to other learning domains, specifically language and literacy.

The research battery of tests used with the children in this study was devised to reflect their experiences. It was felt that the 4 and 5-year-old

children would respond most readily to tests that were child-friendly and were enjoyable for them. This meant considering not only the rhythmic nature or tempi of the musical stimuli, but also a more complex musical experience that included all the elements of music that integrate together to make up ‘music’.

In order to achieve this aim I embarked on a period of study and research in the Faculty of Education in Cambridge in 2006 to gather quantitative

. The initial aim was to devise musical activities that would establish which aspects of the music (rhythm, pitch, harmony, tempo etc.) would best correlate with a series of both cognitive and phonological awareness tests. In a Masters study (2006-2008) the musical and phonological skills of 40 children were tested. The results revealed that they performed both tapping and singing tasks most accurately at pulse rates of between 100 – 120 beats per minute and these tasks were performed equally well to culturally appropriate music. The children’s reaction to both a simple auditory input – a metronome beat and a ‘complex’ musical experience that included instrumental arrangements was compared, and it was discovered that they had a slight preference for the more complex auditory experience. Music played at the pulse rate of 120 beats per minute also correlated with the children’s

responses to rhyme and syllable tests leading to the hypothesis that there could be a biological reason for this relationship.

This PhD is designed to investigate this possibility further. It also aims to contribute both to the understanding of the possible relationship between phonological awareness and musical performance and to the question of which musical activities might best be used to help children acquire pre-reading skills. The PhD is divided into two parts. The first study, conducted within one school year, looked at the relationship between phonological awareness and the perception and production of musical skills by five-year-olds. The second study, conducted during a second school year, replicated the correlational analyses of relationships between sets of phonological awareness and musical skills in Study 1. In addition the effects of a seven-week intervention programme designed to compare and improve pre-reading skills was investigated. The interventions compared the impact of a rhythmic programme on phonological skills delivered in either music or in a rhythmic speech based form. The intervention study was designed to provide data relevant to the hypothesis that certain musical activities bolster phonological awareness that, in turn, improves reading readiness and acquisition of reading in young children.

1.1 The need for the study within the educational context.

Early literacy development is an area of focus among educators and researchers, since low levels of literacy are a problem among children and adults in the United Kingdom and the problem is particularly pronounced in areas of high unemployment and social disadvantage. The children targeted in this research often come from disadvantaged backgrounds. Many have poor speech and language skills and are at considerable risk of language delay. Locke et al (2002) found that more than half the children entering four nurseries in an area of social and economic deprivation were delayed in their speech, language and communication needs. Research by Lonigan and colleagues (e.g., Lonigan, 2004b; Lonigan, Burgess, Anthony, & Barker, 1998) and others (Hecht, Burgess, Torgesen, Wagner, & Rashotte, 2000) has shown consistently that preschool and early school-age children from lower income backgrounds and those whose parents have less education

demonstrate lower phonological awareness skills than more affluent peers. This discrepancy holds for the other key emergent literacy skills of print knowledge and oral language as well. Data indicates that there is a persistent gap in skill level and in rate of new skill acquisition (Lonigan, 2003, 2007a, 2007b). Current theory suggests that these social class differences in early skill levels are likely to be related to early language environments and vocabulary development (Lonigan, 2003, 2007b) as well as to the general home literacy environment (e.g., Evans, Shaw, & Bell, 2000; Phillips & Lonigan, 2005). Such findings suggest that instruction in phonological awareness and other emergent literacy skills is especially critical for preschool children from these at-risk backgrounds if early education is to meet its goal of closing the gap in educational achievement for children who grow up in conditions of poverty.

To address this issue requires enormous resources from government and those responsible for remedial action such as Speech and Language therapists. These services are overstretched and so pre-school teachers have to find appropriate, and often creative ways in which they can help their children to communicate and learn the early literacy skills that will eventually help them to become successful in reading, writing, and other academic tasks.

The situation in the South East of Northumberland is not atypical. Approximately 50% of children in socio-economically disadvantaged populations have speech and language skills that are significantly lower than those of the same age (Lindsay & Desforges, 2008). Lindsay and Desforges noted that approximately 7% of 5 year-olds or nearly 40,000 children going into school in 2007 in England had significant difficulties with their language and are in need of targeted help. About 40% of these 7% of children will catch up within their early years school environment, but about 60% will not, and their deficits will carry on into later schooling and adulthood (Dockrell, 2000). However with appropriate intervention there is evidence that these children can be given help and support to achieve age - appropriate standards of literacy. In a report published in 2013 (ECaR)⁴ research from the Institute

⁴ ECaR – Every Child a Reader.

of Education in London found that a reading recovery programme designed to address the complex needs of the 7% of children, noted by Dockrell, could be successful. In a sample of 374 children who had completed the 'Reading Recovery' programme at the age six, 95% went on to attain National Curriculum Level 3 or above in Reading and 98% in writing at age 11. 78% achieved Level 4 or above in reading and 69% in writing (European Centre for Reading Recovery, 2012). These were the children predicted to fail to reach Level 3. However if children are not given appropriate support the consequences of these early speech and language difficulties often lead to social difficulties and almost certainly lead to problems with reading, indeed children with reading difficulties are also likely to have social difficulties. (Lindsay, (2007).

The ability to read fluently is therefore a critical skill. As demands for literacy increase in our society, the consequences for those who cannot read fluently become more severe. Research has found that children who make a slow start in reading acquisition do not typically catch up to their age peers (Juel, 1988; Torgesen & Burgess, 1998). One Australian study noted that by Year 10, the lowest 10 per cent of students had made no reading gains since Year 4 (Hill, 1995).

According to Morris et al (2006) phonological awareness problems are present in as many as 73% of children with reading disability and Shaywitz (2006) estimated this as even higher at between 80 to 90%.

1.2 Government Intervention

Because so many children have a reading problem, and so many children could be helped with targeted interventions there have been numerous attempts by various Education Secretaries of State in the UK to find solutions that will enable schools to teach literacy effectively.

Various international surveys, including that compiled by the Organisation for Economic Co-operation and Development (OECD) in 2007, suggested that the reading skills of school children in the UK were poorer than those in other countries including Poland, Sweden, the Netherlands and Japan and the UK had dropped from 7th in the league tables in 2000 to 17th. *(In 2010 the same agency placed the UK at 25th in the league table.)*

In consequence of this, the UK Government reacted to adverse press and parental concern over the effectiveness of schooling coverage and instigated a new reading scheme. Despite little reliable evidence (Wyse, 2008) certain educational advisors, consulted for the Rose report (2006), decided that a programme of ‘synthetic phonics’ that concentrated not on syllables and onset/rime awareness but on phoneme manipulation and grapheme – phoneme correspondence would improve literacy teaching. The evidence for this decision came after viewing the results from a relatively small scale training programme, which used a programme of synthetic phonics in Clackmannanshire, a deprived region in Scotland. The researchers (Johnston and Watson (2003 and 2004) studied 300 4/5 year old children in 8 primary schools and claimed that after 16 weeks of training the children were 7 months ahead of both their chronological age peers and a control group who were taught by a more traditional analytic⁵ phonics programme. The children maintained their superior progress over three years. In England the impact of this research was furthered by reports to the Dfes (Brooks 2003) and the Dfes Rose Report itself (2006) and seemed to be justifiable by the research on the effectiveness of phonemic awareness by Hulme et al (2002) who had asserted that “ *Phoneme awareness is a better predictor of early reading skill than onset/rime awareness*”.

Therefore, in September 2008, all children in English schools, starting in their reception classes, were trained in a programme of synthetic phonics⁶ to prepare them for reading.

‘One system fits all’ does not seem to be a useful educational philosophy. Walton (2002) in his studies on acquiring literacy with first nation Canadians concluded that both onset/rime and synthetic phonics approaches were useful, and broadly equivalent in efficacy, and this would certainly seem to be the more balanced approach. Some children will be able to access the written word through their ability to hear small constituent parts of words and others will need to concentrate on larger units, or a combination

⁵ Analytic phonics refers to an approach to the teaching of reading in which phonemes associated with particular graphemes are not produced in isolation. Children identify (analyse) the common phoneme in a set of words in which each word contains the phoneme under study.

⁶ Synthetic phonics refers to an approach to the teaching of reading in which phonemes (sounds) associated with particular graphemes (letters) are pronounced in isolation and blended together (synthesised)

of both. In English it is likely that many children would benefit from trying to disentangle the speech stream by searching for the onset/rime, because this is a more consistent feature of the spoken language (De Cara and Goswami, 2002).

1.3 Need for the Study

The approach by the Department of Education to insist on one methodology of training does not take into account the many differences in ability that children have, nor does it really take into account the readiness of some children to learn to segment words into their smallest component parts (phonemes).

In the Government initiated programme for pre-school literacy training 'Letters and Sounds' (2007) considerable emphasis is therefore placed on the children learning the sound and shape of individual letters, and then phonemes from the outset of their literacy training. There are a few references to other methodologies that could contribute to improved reading such as singing and chanting rhymes :-

"Good teaching will exploit, for example, the power of story, rhyme, drama and song to fire children's imagination and interest, thus encouraging them to use language copiously" Letters and Sounds - pg 6.

– but there is little guidance as to the amount of time needed to spend on this task, or how to assess when the children will be ready to move on from this crucial stage. The programme seems to rely on the work that carers and teachers will have tackled in pre-school from a curriculum for early language acquisition documented in the 'Foundation Stage Profile (2008). In the phase titled 'linking sounds and letters' (LSL) from the 'Communication, language and literacy' part of the profile there is reference to work with rhymes:-

"The child is aware of rhyme in songs and poems and sometimes distinguishes sounds of personal significance from others or notices when words begin with the same sound." Foundation Stage Profile - pg 46.

There is no reference to activities or games that might help the children play with the concept of rhyming and thus gain a deeper understanding of the

sounds and significance of being able to manipulate and have fun with the ‘rimes’. Neither is there reference to games that might help the children segment words into larger units such as syllables. Researchers such as Treiman and Zukowski (1991) assert that the ability to manipulate words into syllables is a key area of phonological awareness training that will lead to improved reading skills because this skill reflects the acoustic properties of speech.

Because of the lack of coherent instruction for teachers and carers in these key areas of phonological awareness it is important to increase understanding of the importance of training in rhyme and syllable awareness, and in so-doing give the children greater opportunities to experience and work with the underlying concepts involved in pre-literacy activities.

1.4 Practical contributions

This study will offer both theoretical and practical solutions due to its focus on the relationship between aspects of music perception and phonological awareness. There is a need for studies that investigate this relationship by isolating the specific effects of music, while taking into account other contributing factors. This research should provide a foundation for musical interventions that mediate change in specific skills in phonological awareness in young children, and thus contribute to emergent literacy.

If the results support the role of music in predicting phonological awareness, they could benefit a variety of professionals, such as early childhood specialists, primary teachers, reading specialists, and special educators who work to promote emergent literacy. This investigation’s findings should provide research evidence necessary for the development of music-based interventions to promote phonological awareness.

Specifically, music therapists could use this study’s findings to develop music-based interventions to benefit individuals with dyslexia. Some children with dyslexia appear to have difficulty with rapid, temporal processing, or the perception of sounds presented rapidly (Tallal, Miller, & Fitch, 1993; Wolff, 2002; Thomson 2008; Huss & Verney 2011). Although these children often do not show difficulty in certain musical skills, such as pitch discrimination,

they tend to show deficits in timing skills in music, such as accurately perceiving, copying, and tapping rhythms (Overy, 2003). Difficulties with rhythmic timing perception may be a contributing factor to difficulty with the segmentation of speech into syllables in some children with dyslexia (Goswami, 2001, 2011; Overy, 2003). Interventions based on discrimination of rhythmic patterns could be used in order to foster skills in syllable segmentation.

Another practical contribution of the current study is that it will provide a foundation for future research investigating the effect of music-based interventions to promote emergent literacy, including phonological awareness, in typical children and children at high risk for dyslexia and other reading disabilities. Thus an understanding of the overlapping neural mechanisms involved in music perception and phonological awareness would provide future studies with a foundation regarding the effects of specific music therapy interventions. Furthermore, this study's results may provide a foundation for previous and future studies that recommend the use of musical interventions to promote emergent literacy (Goswami, 2012).

1.5 Research Focus and Design

The research explored within this thesis is dependent on finding evidence for these overlapping neural mechanisms that will facilitate cross-domain connections between the learning of pre-literacy skills and rhythmic activities, especially music, in the context of an early-years school curriculum in England. Within recent years evidence has been accrued to suggest that this task, although difficult, is not impossible. The research focus and design of the study seeks to shed light on the individual components – phonological awareness and music, and then suggest by way of the methodology and results how they interact and compliment each other.

Both speech and music unfold in time, and rhythm or periodicity is central to the sequential organisation of sounds in both domains. This principle is central to the 'temporal sampling theory' of Goswami (2011) that underlies the hypotheses and methodology employed in this study because it

seems likely that the perception of rhythmic timing is important for the development of language and phonology via the accurate encoding of speech.

The temporal sampling framework has implications for normal language development and the developmental relations between rhythm perception and phonology. Originally Goswami's (2011) framework was intended to organise developmental data showing relations between rhythmic entrainment, rise time discrimination and phonological processing in children with developmental dyslexia and SLI but she also noted that this theoretical framework, along with that of Kotz and Schwartz (2010) had implications for both language development and for the perception of music. Kotz and Schwartze (2010) proposed that speech perception is inherently linked to rhythmic timing via the perception of rhythmically prominent syllables. They argued that these (stressed) syllables could play an important role in speech perception, providing a temporal structure that might be used by the brain in encoding and understanding speech.

Human '*dynamic interaction*' with patterns of sound events in the world is a form of entrainment (London, 2004 pg 5). When the sound events are rhythmic in nature, occurring periodically or with perfect isochrony,⁷ this dynamic interaction is termed rhythmic entrainment. Rhythmic entrainment can be active, as in tapping along with a beat, or passive, as in tasks that require sensory perception of forthcoming events (Large & Jones, 2002). In children with language disorders such as developmental dyslexia and specific language impairment (SLI), individual differences in active rhythmic entrainment to an isochronous beat at 2.5 Hz (400 ms), 2 Hz (500 ms) and 1.5 Hz (666 ms) have been found to be predictive of individual differences in phonological development (Thomson and Goswami, 2008; Corriveau and Goswami, 2009). Children with dyslexia and SLI usually have phonological difficulties. These experimental investigations have raised the possibility that individual differences in the accuracy of rhythmic entrainment may be important for the development of language and phonology. It is therefore equally important to measure the accuracy of entrainment in young typically developing children and its relations (if any) to language and phonological

⁷ A sequence of events is isochronous if the events occur regularly, or at equal time intervals.

development as well. The temporal sampling framework makes some clear developmental predictions about the relationship between rhythmic entrainment at syllable-relevant rates and phonological development in typically developing children. This study seeks to explore these predictions in a sample of 192 young typically developing children aged 4 – 5 years.

The study also engages with a third theoretical framework offered by Cummins (2010) who argues for the core role of motor processes in perceiving and producing rhythmic speech events. “When speech is turned into chant, rap, verse or song, we find a marriage of rhythm in the musical and phonetic senses. When children in the playground turn a single exclamation or taunt into a repeated mantra, its rhythmic potential is unleashed” (Cummins, 2010, p. 6). Cummins notes that although speech appears highly specialised and detached from general bodily rhythms, in fact it shares the same rhythmic constraints of any cyclic movement of the limbs (walking, dancing, juggling...). Cummins argues that speech is a whole-body activity, and in some key respects is similar to musical performance. His view is that rhythm in speech and rhythm in music are related via embodiment and entrainment. We know that children and adults cannot help tapping along or internally feeling the rhythm whilst listening to music but this understanding of feeling the internal rhythms in language is far less studied. Cummins (2010) makes a very plausible case that there should be important links between rhythmic embodiment and linguistic behaviour. With this in mind it is therefore important to assess the links between young children’s performance in rhythmic and musical tasks and their linguistic behaviour and find relevant data that brings together the two domains. In the current study, the rhythmic entrainment and musical tasks involved embodiment, as they involved whole-body activity (Bongo drumming with two hands and singing).

These different theoretical perspectives linking language and music place entrainment at the core of rhythmic behaviour, and suggest that there should be important developmental links between rhythmic entrainment, language and music. Developmentally, these different (yet mutually consistent) theoretical frameworks would predict that those children who show more accurate rhythmic entrainment should also show superior musical

and linguistic performance. For example, children who are more accurate in rhythmic entrainment tasks should also be more accurate at singing in time with music. There should also be relationships between individual differences in rhythmic entrainment and individual differences in aspects of linguistic development such as phonological development.

A recent study of rhythmic entrainment via drumming in children aged 2.5, 3.5 and 4.5 years of age demonstrated that young children can drum along with others and perform this task with reasonable accuracy (Kirschner & Tomasello, 2009). The children were required to synchronise their drumming with an external rate of either 400 ms or 600 ms. Although language skills were not measured, children at all ages showed significantly more accurate entrainment when drumming with a social partner (drumming along with the experimenter rather than with a drum machine). This research gives credibility to the principle methodology employed within the study, (assessing the rhythmic accuracy of children drumming to various rhythmic stimuli) as it confirms that children of pre-school age can synchronise accurately to music or metronome beats. It was, therefore, possible for me to use these reliable means of measuring entrainment to assess links between rhythmic accuracy and phonological awareness skills at the syllable and rhyme levels.

I propose that one aspect of rhythmic timing that is important when investigating possible developmental links between rhythmic entrainment and language/phonology is the entrainment rate. The studies with dyslexic children of Thomson and Goswami, 2008; Corriveau and Goswami, 2009) used the 2.5, 2 and 1.5 Hz rates in their tapping tasks that involved entrainment to a synthesised metronome beat. I, however, thought it useful to add a fourth slower rate of 1 Hz (1000ms), especially since I was using musical stimuli, and it has been shown that even young children could synchronise accurately to this slower rate if music was involved (Drake, 2000). In many previous studies investigating synchronisation and entrainment to a fixed pulse rate a simple metronome sound has been used (Fraisse et al. 1958 to McCauley, 2006). This study seeks to investigate whether a series of musical excerpts with which the children are culturally

familiar in terms of rhythms, harmonisation and instrumentation are equally effective in providing a framework for testing accuracy whilst synchronising to a series of differing pulse rates.

It is currently unknown as to whether there is a biologically preferred rhythmic rate that ties together different forms of motor entrainment with linguistic development. One possibility is that 500 ms (2 Hz) could be such a biologically special pulse rate (see Huss and Verney, 2011). MacDougall and Moore (2005) studied the spontaneous tempo of walking in humans, and found that preferred gait was 2 Hz irrespective of gender, height, weight, age or body mass index. They suggested that 2 Hz (500 ms) could represent a spontaneous tempo or “resonant frequency” of human movement. This observation is consistent with a number of developmental and linguistic studies of spontaneous tempi. Once children are older (8 years and above), 500 ms is their preferred spontaneous tempo. The spontaneous tapping rate is one at which we choose to tap in the absence of an external timekeeper (McAuley et al., 2006). Adults also converge on a rate of 500 ms when asked to tap in time with different kinds of music (Moelants, 2002). Across languages stressed syllables are produced on average every 500 ms (Arvaniti, 2009), suggestive of a biological constraint linked to the articulators, and when adults read aloud from text, they show a bias for inter-stress intervals which are multiples of a 500 ms unit (Fant and Kruckenberg, 1996). Links between rhythmic entrainment and linguistic development might be expected to be strongest for temporal rates at 2 Hz, thus, possibly showing a privileged relationship.

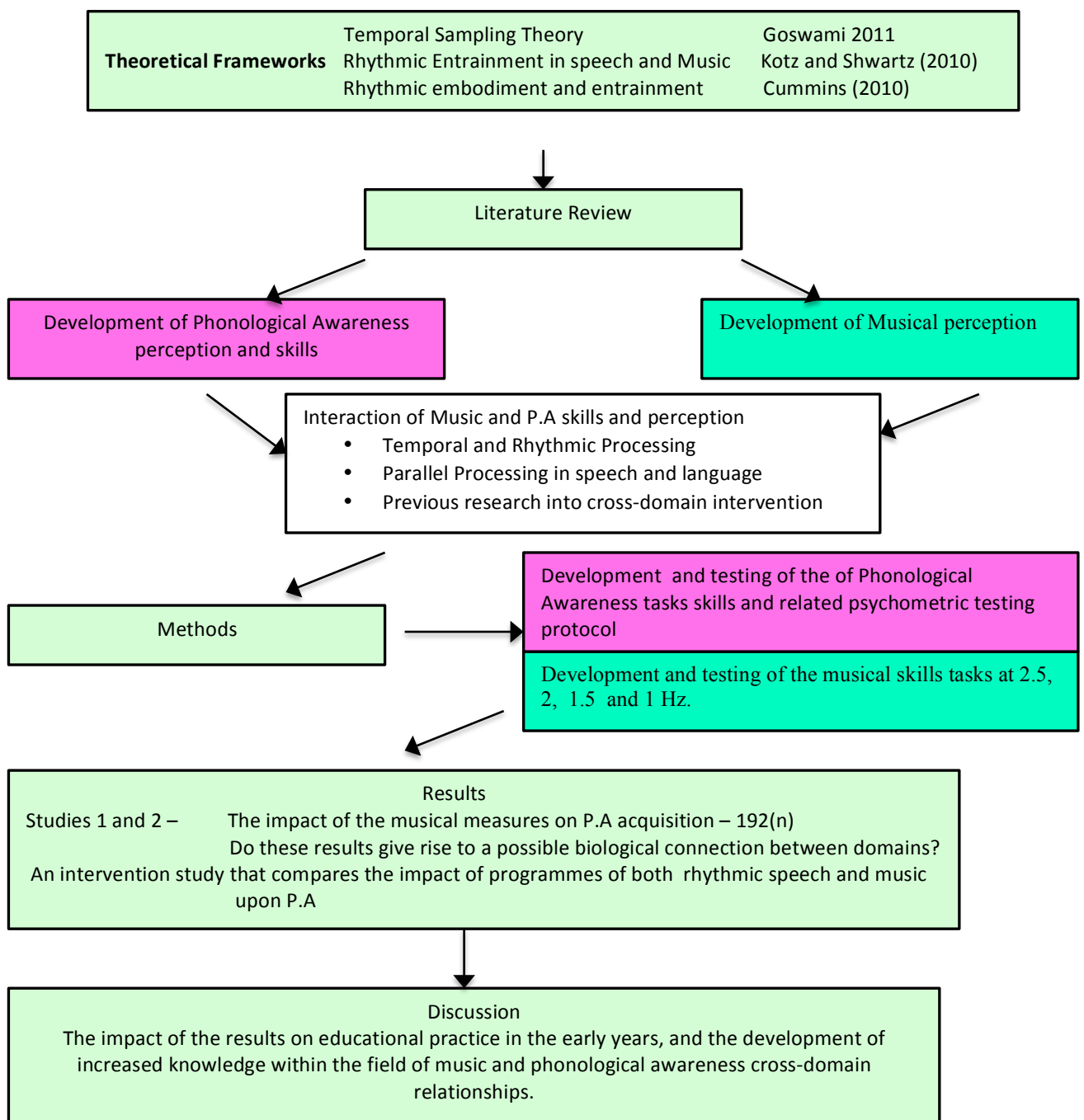
This short exposition of the research area provides a framework for the design of the study:-

1. The literature review expands on the various aspects of phonological and music processing that is relevant to the study, and how they are linked together. It provides a framework for the various hypotheses and research questions explored within the study.
2. The methods section explains the design of the tasks and the profile of the participants.
3. The results show the findings of two studies designed to discover whether there is a biological bias towards one particular pulse rate that is present in both children’s processing of both P.A and rhythmic perception in music.

4. The results of an intervention study investigates are investigated to assess the possibility that a programme of rhythmic speech can be as equally effective as a programme of music in improving a pre-school child's phonological awareness.
5. The final discussion revisits the research questions and discusses the findings in both educational and scientific contexts.

Table 1.5

*Rhythmic Perception and Entrainment in 5-Year-Old Children.
Research Focus and Design*



Chapter 2. Literature Review

<i>Table 2.1. Glossary of terms Phonological Awareness</i>	
Phonology	Phonology is a branch of linguistics concerned with the systematic organization of sounds in languages. It has traditionally focused largely on study of the systems of phonemes in particular languages, but it may also cover any linguistic analysis either at a level beneath the word (including syllable, onset and rhyme. It can also refer to the phonological system (sound system) of a given language.
Phoneme	A phoneme is a basic unit of a language's phonology, which is combined with other phonemes to form meaningful units in words. The phoneme is "The smallest contrastive linguistic unit which may bring about a change of meaning". In this way the difference in meaning between the English words kill and kiss is a result of the exchange of the phoneme /l/ for the phoneme /s/.
Onset - rime	Monosyllabic words can be split into two parts - the onset and the rime - each of which are smaller than syllables, but may be larger than phonemes. The onset is the initial consonant sound (b- in bag, sw- in swim), and the rime is the vowel and the rest of the syllable that follows (-ag in bag, -im in swim).
Synthetic phonics	Synthetic phonics is a method of teaching reading which first teaches the letter sounds and then builds up to blending these sounds together to achieve full pronunciation of whole words.
Analytic phonics	Analytical Phonics refers to an approach to the teaching of reading in which the phonemes associated with particular graphemes are not pronounced in isolation. Children identify (analyse) the common phoneme in a set of words in which each word contains the phoneme under study. For example, teacher and pupils discuss how the following words are alike: pat, park, push and pen.
Large grain	Large grain = Awareness of whole word sounds and syllables and rime patterns – useful for mapping orthography in inconsistent orthographic languages (English).
Small grain	Small grain = Awareness of phonemes – most useful for mapping orthography in consistent language orthographies (German).
Orthography	An orthography is a standardized system for using a particular writing system (script) to write a particular language. It includes rules of spelling. Other elements of written language that are part of orthography include hyphenation, capitalization, word breaks, emphasis, and punctuation.

“ Every human infant is born into a world with two distinct sound systems. The first is linguistic and includes vowels, consonants, and pitch contrasts of the native language. The second is musical and includes timbres and pitches of the culture’s music. Even without explicit instruction, most infants develop into adults who are proficient in their native language and who enjoy their culture’s music.” Patel 2008 - pg 9.

The literature review is divided into five key areas. The first section highlights research related to phonological awareness; defining this construct and examining its developmental sequence. The second section follows a similar analysis for the second construct: musical perception. The third section looks at auditory temporal processing. The fourth section summarizes parallel auditory processing as it applies to music perception and phonological awareness. The fifth section examines previous studies investigating the relationship between phonological awareness and music perception in five-year-old children. The literature review provides a foundation for the theory under investigation regarding the temporal relationship between music perception and phonological awareness in five-year-old children.

2.1 *Phonological Awareness – the underlying sounds of a language*

Phonological awareness refers to the sound structure of the language and the skills required to perceive, manipulate and blend sound units (Ehri, 1989; Dodd, 2001; Anthony and Francis, 2005). This ability develops gradually from a very early age.

An ability to recognise and manipulate words, syllables and rhymes has been shown to be a key predictor of future literacy success (Bradley & Bryant, 1983; Bryant, MacLean, Bradley, & Crossland, 1990; Lundberg, Frost, & Petersen, 1988; Schneider et al 1999). The corollary of this is that a large number of studies have shown that poor phonological awareness skills characterize poor readers. If the child has poor perceptual, processing, and cognitive skills required to identify and isolate individual sounds in words and pair sounds with letters they will find reading difficult. Consequently, performance on phonological awareness tasks is an excellent predictor of later reading success or disability (Goswami & Bryant, 1990; Scarborough,

1998; Wagner & Torgesen, 1987). Torgesen (2002) reviewed research-based practices in early reading instruction and found that phonological awareness is a valid predictor for the identification of children at risk for reading problems. Previously Bus and van Ijzendoorn's (1999) study of the reliability of 34 training programmes to improve literacy found that phonological awareness was a key factor and to disprove this would take more than 500 new studies.

To acquire reading, children must learn the code used by their culture for representing speech as a series of visual symbols. One core aspect of learning to read is therefore a process of matching distinctive visual symbols to units of sound (phonology).

Zeigler and Goswami (2005) assert that:-

"To acquire reading, children must learn the code used by their culture for representing speech as a series of visual symbols. Learning to read is thus fundamentally a process of matching distinctive visual symbols to units of sound (phonology)" pg 3.

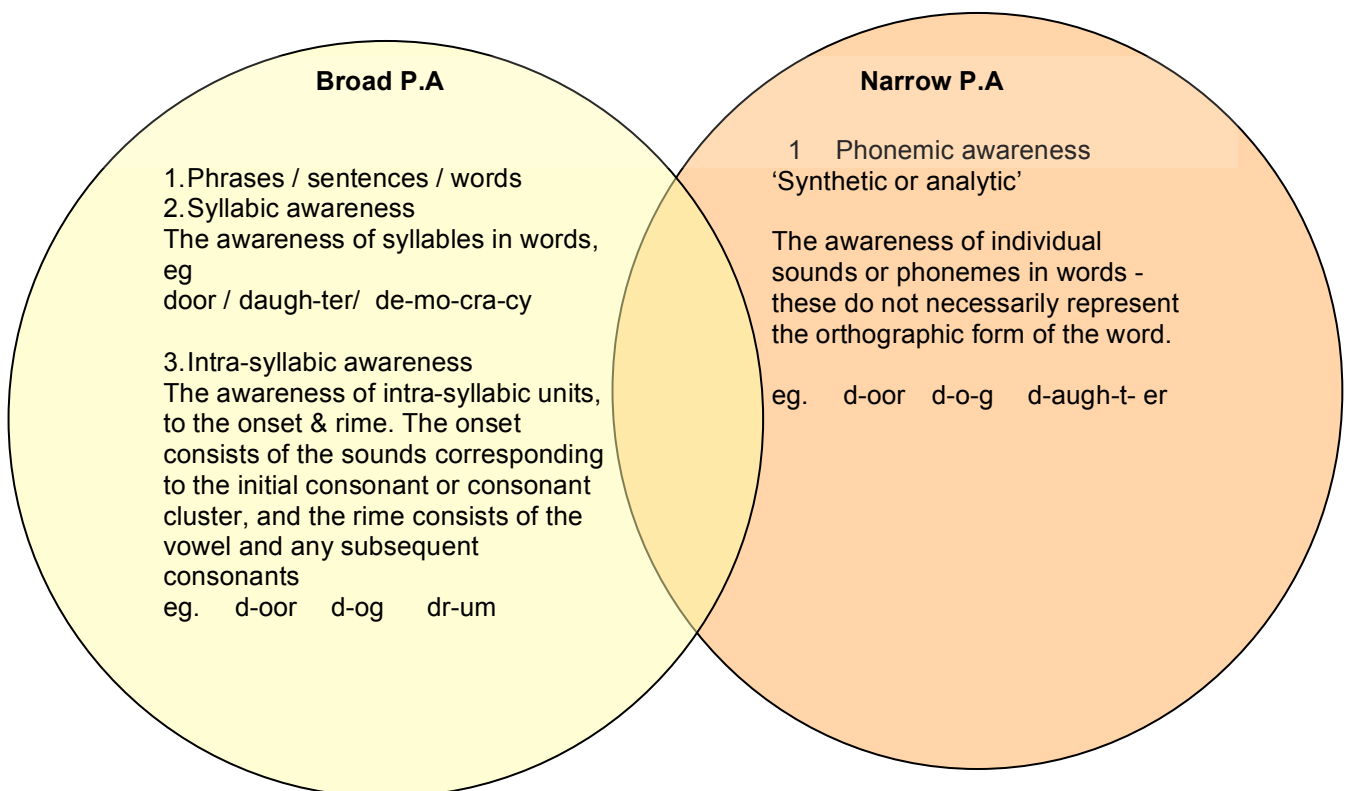
In most languages, the relationship between symbol and sound is systematic, for example, in English, the symbol D is almost always pronounced /d/. A child learning to read English can exploit regularities like this to access the phonology of words. In contrast, knowing that a word starts with the letter D tells the child nothing about its meaning. The first steps in becoming literate, therefore, require acquisition of the system for mapping between sound and symbol. When this is mastered it allows children to access the thousands of words already present in their speech.

Before this can take place the child needs to demonstrate an understanding of phonological awareness. They must be able to perceive, attend to, and discriminate units in a sound stream. Children must then relate these linguistic components to their spoken vocabulary. They need to recognise whether initial, middle, and ending sounds in different words are the same or different from each other. In order to identify and reproduce the beginning or ending sound in a word, a child must perceive the sound, and then compare it to a repertoire of previously learned and practised sounds. They must also recognize linguistic sound categories in spite of variations in pitch, tempo, speaker, and context (Anvari et al., 2002).

Phonological awareness skills involve three related groups of abilities: phonological sensitivity (Stanovich (1992), phonological naming, and phonological memory (Whitehurst & Lonigan, 2001; Wagner, 1993). Phonological sensitivity involves the detection and manipulation of sounds in oral language. Children need to identify words that rhyme, blend syllables or phonemes to form words, or count the syllables or phonemes in a word.

Phonological naming involves retrieving phonological information from long-term memory, for example, looking at a page with different-coloured squares and quickly identifying the colours verbally (Whitehurst & Lonigan, 2001). Phonological memory, involves short-term memory of auditory information, for instance, a child's ability to recall a series of sounds or words. Phonological sensitivity, phonological naming, and phonological memory are all essential for emergent decoding of written words.

Figure 2.1. A brief explanation of terms for phonological awareness (P.A)



2.1.1 Developmental Sequence For Phonological Sensitivity

The child progresses gradually from awareness of larger (*broad*) units to increasingly smaller (*narrow*) ones. (Figure 2.1.) Therefore children become aware of words, syllables, then intra-syllabic units (onset - rime) and finally phonemes. In a 2003 study Anthony et al. used a large group of participants (more than 1,000 children), and a wider age range than in previous studies (2–6 years), to investigate the order of acquisition of phonological sensitivity skills at various grain sizes while holding constant the type of operation that was performed (e.g., blending, deletion). The results clearly showed that children’s progression of sensitivity to linguistic units followed a hierarchical model of word structure (Zeigler and Goswami, 2005) shown in Figure 2.2. That is, the children generally mastered word-level skills before they mastered syllable-level skills, syllable-level skills before onset–rime skills, and onset–rime-level skills before phoneme-level skills, controlling for task complexity.

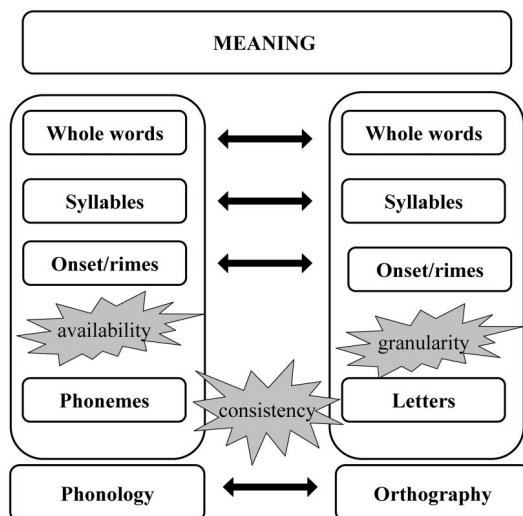


Figure 2.2 Sequence of Acquisition of P.A. from Zeigler and Goswami 2005

In their theory of ‘psycholinguistic grain size’ Zeigler and Goswami (2005) matched the transition from broad and narrow phonological awareness to a transition from large grain to small grain units in many languages and found that the progression was not limited to spoken English or German. Their 2005 investigations found that children from many different countries, certainly those in Europe, moved from large units to smaller ones (Goswami et al. 2003) when decoding their language

As children become more sensitive to the acoustic qualities of speech

their ability to detect and manipulate units that reflect the different parts of speech associated with phonological sensitivity improves. They become more able to discriminate and manipulate “small” segments of sounds or phonemes. Increased awareness of the smaller units leads more directly to being able to link the sounds of the phonemes to letter recognition, and then onto reading by enabling sound letter correspondences and reading by analogy (Baron, 1977; Byrne & Fielding-Barnsley, 1991; Goswami, 1993; Walton, 1995). Children gain an understanding of syllables earlier than they achieve phoneme sensitivity, and children achieve sensitivity to intra-syllabic units (i.e., onsets and rimes) before they achieve sensitivity to phonemes (Fox and Routh, 1975; Liberman, 1974; Treiman, 1992, Treiman 1991).

Researchers largely accept this sequence, but what is still controversial within this field is which particular area within the sequence of phonological awareness acquisition is the greatest indicator of future success in reading. Some researchers have claimed that the ability to manipulate the phoneme is the most significant factor (Hulme 2002), others claim that other factors such as the child’s ability to manipulate syllables (Treimann 1992), or onset/rimes is a better indicator (Carrol and Snowling 2001). This argument was given much attention in an edition of the *Journal of Experimental Child Psychology* (82) in 2002 and further reviewed by Zeigler and Goswami in 2005.

When comparing tasks it is important to ensure that the child has the cognitive capacity required for the particular tasks being used and that measurement problems like floor effects, ceiling effects and low reliabilities have been attended to.

To address these issues Anthony and Lonigan (2004), used confirmatory factor analysis and structural equation modelling to more precisely quantify the longitudinal relations among phonological skills. Their analyses included data sets from four studies used by their original authors to argue for the pre-eminence of the phoneme (Muter, Hulme, & Snowling, 1997; Muter, Hulme, Snowling, & Taylor, 1998) and overall incorporated 1,189 children from 3 to 7 years old. Their results indicated that sensitivity to syllables, onsets, and rimes were as much a part of the construct of phonological awareness as sensitivity to phonemes and that conclusions to the contrary were due to ignoring floor effects and the inappropriate use of

exploratory factor analysis. Anthony and Lonigan (2004) concluded:-

“In summary, it appears that the debate over whether sensitivity to rhyme or sensitivity to phonemes is most important for reading and spelling has led researchers and theorists astray . . . The important question . . . is not what type of phonological sensitivity is most important for literacy but which measures of phonological sensitivity are developmentally appropriate for this particular child.” pg 53

Pre-school children generally demonstrate a good understanding of most aspects of phonological sensitivity. However, this, to a large extent, is dependent on giving them the right training and experience so they can demonstrate their knowledge. Within a curriculum that focuses almost exclusively on letter sounds the importance of sensitivity to both rhyme and syllable awareness would seem to be becoming marginalised, and yet recent research still confirms their developmental importance in acquiring a good understanding of the sounds of the child’s language.

The design of the research used in this PhD focused on the children’s ability to segment syllables and their rhyme awareness, and tests were used to correlate rhythmic awareness with these two aspects of phonological sensitivity.

2.1.2 Sensitivity to Rhymes

By the age of 4½ - 5 years old, the age at which the children in these studies were tested, the majority of the children should do well in rhyme-related tasks. This is a well-established research finding, and has been explored and reconsidered over a period of some 40 years (Calfee, Chapman & Venezky, 1972; to Walton, 2010). The ground-breaking work of Bradley and Bryant (1983, 1985), now nearly 30 years old, showed how remedial readers could become more successful if they had increased knowledge of nursery rhymes. They reported that sensitivity to rhyme and alliteration prior to a child’s entry to formal schooling plays a causal role in their reading success several years later. Furthermore, in their research the authors reported

that receiving explicit instruction and training in the areas of alphabetic principles, rhyming, identification of words and alliteration strongly and positively affected children's reading ability. In a subsequent longitudinal study (MacLean et. al. 1987), authors provided systematic evidence that knowledge of nursery rhymes played a role in children's phonological development. Covering a 15-month period, beginning when children were age 3.4, data were collected to measure children's knowledge of five common nursery rhymes. Findings reported that children's initial nursery rhyme knowledge was a powerful predictor of their growing skill in rhyme and alliteration detection tasks over the next year and a quarter. Bryant et al. (1989) reported further longitudinal data from a group of 64 children ranging from ages 3.4 to 6, covering a three-year period supporting the hypotheses that acquaintance with nursery rhymes positively affects children's reading ability. Data report a strong relation between early knowledge of nursery rhymes and success in reading and spelling, despite differences in social background, intelligence quotient, and beginning phonological skills.

In a study undertaken to determine which factors contributed most strongly to children's ability to learn to read by analogy, Wood (1999) found that a subgroup of participants (mean age = 5:8), who performed poorly on a rhyme detection task, also performed poorly on a phoneme deletion task. Walton and Walton (2002) performed a study in which pre-reading kindergarten children were taught either rime analogy and/or pre-reading skills including rhyming, initial phoneme identity, and letter-sound knowledge. They found that children specifically taught all of these components were more successful than those taught one or the other in developing reading skills. Furthermore, they found that rhyming accurately distinguished readers from non-readers. Schneider, Ennemoser, Roth, and Küespert (1999) showed that phonological awareness tasks (e.g. phoneme analysis and synthesis, identification and deletion of initial phonemes, alliteration and rhyming) could be taught before children learned to read and spell. They also noted that children who were trained in these skills continued to benefit from such training at least four months later. In the studies of Vloedgraven and Verhoeven, (2007, 2008) one of which had 1400 participants, concerning the predictive nature of phonological awareness to

reading, they found that rhyming performance appeared to be the easiest and most accessible aspect of phonological awareness in their kindergarten sample. It was equally as important as the phoneme identification, phoneme blending, and phoneme segmentation tasks in accurately measuring the children's phonological awareness. Their studies did not involve specific training, but simply addressed the general trends of development over time, and how the influence of phonological awareness skills on reading declined as the children were given more specific training in reading. Their studies also confirmed the theories that propose that there is a developmental progression in the acquisition of phonological awareness from larger to smaller phonological units (e.g., Anthony & Francis, 2005; Ziegler & Goswami, 2005). Their results also confirmed the findings of Lonigan et al. (2000) and Anthony et al. (2002) that suggested that all of the components of phonological awareness represented a single underlying phonological ability.

A study by Majsterek et al. (2000) included 40 three to five-year-old low-income preschool children attending a Head Start programme in Washington State. They compared a phonological processing outcome for an intervention group that participated in rhyme detection training with a comparison group that participated in semantic training (i.e., training that focused on word meanings). Their results showed that because rhyming developed earlier than most other phonological awareness tasks, and because it has been linked to success with reading, then training in that area should begin first and should help promote emergent literacy skills in children who are considered at risk for reading difficulties. Their study showed that, when four minutes of rhyming training was added to children's nine minutes of circle time, the children were able to perform better on rhyme detection tasks than their non-trained peers. Both groups were exposed to rhyming, but only one group received explicit training.

Within most rhyme-based phonological awareness studies the outcome expected would usually be to discover the child's ability to perform a rhyme production, recognition or oddity task (Table 2.1.3). These require a one-word answer. In a nursery rhyme the rhyming word is generally at the end of a phrase, and is part of a sentence or phrase that gives it a semantic context.

The rhyme in this context is dependent on other factors such as stress, duration and position. It invariably comes at the end of a phrase, and certainly in a musical context will have added stress (accent) because it falls on a stronger accented beat in the music.

A ‘word level rhyme’ task could be a more relevant task for a child who is having difficulty isolating individual sounds because some observational studies show that the ability to use ‘word level rhymes’ precedes any segmentation task – be it syllables or onset-rimes (Chukowsky, 1968: Van Kleeck and Schuele 1987). Their observations of spontaneous language play with children of two years of age or even younger have shown that young children play with rhyming words with great enjoyment. Dowker (1989) examined poems from 133 children ranging in age from 2 to 6 years of age. 58% of her sample when asked to ‘compose’ a poem responded with a strongly rhythmic rhyme. Her conclusions from the research project suggested that children have an ability to rhyme before syllable segmentation.

One possible conclusion one can draw from these studies is that the ability to play with rhymes in a song or poem is a very different activity from being able to perform in a phonological awareness skills test. This conclusion is echoed by Lundberg (1978) who emphasised the difference between the implicit level of phonological awareness implied in traditional phonological awareness tasks that require the analysis of words into their constituent elements and those that requires a ‘word-level’ rhyme.

A study reported in 2000 (Gipstein et al) with 249 children between the ages of 4 and 5 years-old, concluded that early literacy should commence in the classroom with an added attention to word-level rhymes because it seemed to be a more ‘natural’ activity for the young children in comparison to ‘rimes’ or syllables. Their study was designed to examine the impact of structural units (syllables and rhyme) in phonological awareness, especially with consideration for the size of the unit. They examined whether it was easier for the child to notice larger chunks of information rather than smaller units. This is once again in line with the ‘psycholinguistic grain size’ theory. (Zeigler and Goswami (2005).

The studies of Walton (2002 – 2010) are particularly relevant within the context of whole word level rhymes in ascertaining the impact of

phonological awareness skills on future reading. His work represents a fundamental shift in how rhyming is presented to the children in intervention procedures – he uses children’s songs and rhymes, as opposed to ‘rhythmic speech’ as his principle methodology.

Although there have been consistent recommendations to use music and song as a vehicle to teach phonological and beginning reading skills (e.g., Habsen, Bernstorf, Stuber, & Gayle, 2004), very little empirical research has examined this question. To address this his team developed a program of teaching ‘beginning reading’ using songs and movement with Aboriginal Kindergarten children in North West Canada to examine the effects of using songs and movement to teach reading. The research capitalizes on children’s inherent interest and the fun in learning rhymes and singing. They found that children appeared to learn new words more easily and remember the words for longer periods of time when jingles were used to teach reading words that rhymed (Walton, Walton, & Felton, 2001; Walton & Walton, 2002). In other research, some of which included Aboriginal children as a subgroup (Walton, Walton, & Felton, 2001; Walton, Thorneloe, Bowden, Kurtz, & Angus, 2001; Walton & Walton, 2002), they also found that children learned to read new words more easily and remember the words longer when jingles were used as a teaching method, and if the words rhymed. This work with children, who in the past have been shown to have difficulties in accessing the literacy curriculum, almost certainly is related to the fact that not only are the rhyming activities fun, but many children as stated find them quite easy to do, and therefore gain confidence in the learning process.

An even more recent study (Harper 2011) looked specifically at the impact of an intervention to improve phonological awareness skills using knowledge and manipulation of words in 10 well known Anglo-American Nursery Rhymes. After a ten-week intervention of two 30 minute sessions per week the 11 children significantly outperformed the control group who had received no additional training (Wilcoxon Signed Rank Test two-tailed tests were administered on the pre and post-test scores). The researcher stressed the fact that nursery rhymes are a socially engaging, playful, and developmentally appropriate way for young children to hear, identify, manipulate, and experiment with the sounds of language. Integrating nursery

rhymes, jingles and chants, and other traditional literature into the early childhood curriculum contributes to a linguistically rich environment in which young children are exposed to the rich vocabulary, syntactic complexity, and decontextualized language contained within the English language. Combining tactile-kinesthetic activities, in which language is intentionally explored, manipulated, and experimented with, within the context of nursery rhymes and literature enhances children's phonological awareness, sensitivity to rhyme and phonemes, and may stimulate phonemic skill development. Although the sample is very small the results match those predicted by Bradley and Bryant (1991).

2.1.3 Sensitivity to Syllables

The evidence would suggest that young children are equally sensitive to syllables as they are to rhymes in pre-school settings. A 2009 résumé (Pufpaff) of the literature on the developmental nature of phonological awareness for school practitioners is shown in Table 2.1.2.

Table 2.1.2

Phonological sensitivity Skills in Developmental Sequence

Skill	Example
Rhyme detection	"Does <i>dog</i> rhyme with <i>log</i> ?"
Rhyme creation	"Change the first sound in <i>dog</i> to make a word that rhymes with <i>dog</i> ."
Rhyme production	"Tell me a word that rhymes with <i>dog</i> ."
Rhyme recognition	"Which word rhymes with <i>dog</i> ? <i>Cup-sit-log</i> ."
Rhyme oddity	"Which word does not rhyme with the other words: <i>fan-cat-mat-hat</i> ."
Syllable blending	"What word is this? Listen. / <i>ta</i> / / <i>ble</i> /."
Sentence segmentation	"Tell me how many words you hear in this sentence. Listen. <i>The boy has a blue hat</i> ."
Syllable segmentation	"Count the syllables in this word. Listen. <i>Elephant</i> ."
Syllable deletion- compound word	"Listen. <i>Cowboy</i> . Say <i>cowboy</i> . Take away <i>cow</i> . What word is left?"
Syllable deletion- multisyllabic word	"Listen. <i>Carpenter</i> . Say <i>carpenter</i> . Say it again without <i>car</i> ."

It is interesting to note the effects of training on this task. All the early research suggests quite strongly that pre-school children find the concept of the subdivision of a word into syllables quite easy, and the segmentation of

words into phonemes more difficult. The present literacy curriculum, as interpreted by many schools, place emphasis on phoneme segmentation – eg a word such as ‘panda’ – is not first and foremost a two syllable word, but it comprises five phonemes. Initially the children in the research for this PhD were confused by the concept of dividing a word into ‘big’ bits (syllables), rather than the smaller letter sound units they were taught in class. In other words they seemed to have to relearn a skill that evidence showed they were able to do. In the English school system there sometimes seems to be a focus on learning to read before the children comprehend the sounds of the language – but as I have discussed above, all evidence shows that early understanding of the larger units of sounds in a language facilitates reading.

Data concerning a young child’s sensitivity and ability to segment words into syllables is very well established. Fox and Routh (1975) assessed the ability of 3 to 7-year-olds to segment sentences into words, words into syllables, and syllables into sounds. All age groups were able to segment sentences into words, and most of the 3-year-olds could segment words into sub-units, although not necessarily at syllable boundaries. Children ages 5 to 7 performed near ceiling level on these two tasks. Their research showed that segmentation of syllables into phonemes was the most difficult task for all pre-school and first grade groups. The 3-year-olds could only segment about 25% of the syllables correctly, whereas the 6 to 7-year-old children segmented more than 85% correctly. There was a marked increase in the ability to segment syllables into phonemes between the ages of 3 and 6 that leveled off between 6 and 7. Goldstein (1976) obtained similar results when assessing 4-year-olds on their ability to segment and blend both syllables and phonemes. The children’s performance with the syllables was superior to that of the phonemes.

Liberman, Shankweiler, Fischer, and Carter (1974) examined the relative difficulty of syllable segmentation compared to phoneme segmentation among children in preschool, kindergarten, and first grade. As expected, syllable segmentation was easier. In fact, none of the children in preschool could segment by phonemes while nearly half (46%) could segment by syllables. Among the kindergartners, only 17% could segment by phonemes, whereas 48% could segment by syllables. Accurate performance

increased dramatically in first grade, with 70% successfully segmenting by phonemes and 90% by syllables. This was one of the first studies to empirically demonstrate syllable-level segmentation was easier than phoneme-level segmentation.

Treiman and Zukowski (1991) asked children whether two words presented to them had any sounds in common. In one condition, the shared sounds constituted syllables (e.g., *hammer- hammock*; *compete – repeat*); in a second, they were onset-rimes (e.g., *plank –plea*; *spit –wit*); and in a third, they were phonemes (e.g., *steak –sponge*; *smoke- take*). Treiman and Zukowski found that the syllable task was easier than the phoneme task at every grade level, and the onset-rime task more difficult than the syllable task. Both tasks were easier than the phoneme deletion task.

In general therefore the research literature shows that pre-school children have difficulty detecting, isolating, and manipulating individual phonemes in words (Bowey & Francis, 1991) because they are an abstract phenomena, but syllables are each distinguished by a ‘vocalic’ centre with well defined acoustic properties and can be produced in isolation.

2.1.4 Implications for the research paradigm

It is important for professionals who work with young children to understand the developmental nature of phonological sensitivity so they can make informed decisions about assessment, literacy instruction, and remediation (Phillips, Clancy- Menchetti, & Lonigan, 2008). When educators understand the order in which young children acquire phonological sensitivity skills, they can better design assessment measures that accurately assess appropriate phonological sensitivity skills in the proper sequence (Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003). More important, providing instruction in phonological sensitivity skills at appropriate developmental levels will contribute to the prevention of later reading difficulties.

The studies of Blachman et al (1994 and 1999) are particularly apposite because she followed a sample of children (n.159) from low income, inner city communities in upstate New York where there was a high proportion of

low on-entry ability. The study found that an intervention based on a phonological awareness program in kindergarten followed by a reading program in grade 1 (and extended to grade 2 for some children) that built on this awareness and emphasized explicit instruction in the alphabetic code demonstrated a significant advantage in reading at the end of grades 1 and 2. The lowest scoring 8% of children at pre-test benefitted most from the intervention programme. The intervention, although quite intensive, was only 11 weeks long.

However in a study in Scandinavia (Lundberg 1991) it was concluded that phonemic awareness could be developed among preschoolers (n.200 - 6 to 7 year olds) by training, without introducing letters or written text.⁸ This has made it possible to examine the critical role of phonemic awareness independent of reading skill and outside the context of reading instruction. The researchers concluded that a more crucial element was explicit guidance of children when they were trying to access, attend to and extract the elusive, abstract, and implicit segments of language.

Because the research literature tells us that young children, particularly those who find difficulty in hearing and interpreting the phonemes in words, would benefit from increased phonological training in hearing and interpreting syllables and rhymes within the speech stream, this will become the focus of the phonological testing in this study. These tests will then be correlated with other psychometric measures and appropriately devised music tests that bring attention to both syllable and rhyme awareness in instrumental music and songs.

⁸ Children in Scandinavian countries do not have reading instruction before the age of 7 due to the relatively late school start and an old tradition that reading is school business.

2.2 Music Perception and Skill Acquisition in the pre-school child

Table 2.2.1 Musical Definitions

1. Rhythm refers to the temporal or durational qualities of music, including beat, tempo, and meter (Hodges & Sebald, 2011). A steady or isochronous beat offers a framework in which the listener organizes sounds.
2. Tempo is related to how quickly or slowly beats occur. Humans can perceive beats starting at 30 beats per minute (bpm) and ranging up to 300 bpm in streams of musical events, but are most likely to infer tempi from basic pulse rates of 60 to 150 bpm. (Thaut 2005). Tempi in music are never stable, but fluctuate. These fluctuations however do not seem to undermine the listeners sense of stability in an underlying pulse. (Large and Palmer, 2002; Madison and Merker, 2002).
3. Meter is an important organizational component in music because it organizes sounds into equal or unequal subdivisions over time (Radocy & Boyle, 2003).
4. Pitch is associated with a tone being perceived as high or low on a continuum (Radocy & Boyle, 2003; Stainsby & Cross, 2009). Frequency or vibrations per second primarily determine pitch; however, pitch is also influenced by other factors, including sound intensity.

Pitch is an acoustic property that allows the listener to identify highness or lowness in a sound (Benward, 1985).

5. Tones. While pitch is a general term, the term tone is used to define pitches with a definite frequency.
6. Notes. In music, tones are called notes and are arbitrarily determined by a set of rules. The Western music system for example, is based on the chromatic scale, or, a series of twelve notes equally separated by units called semitones, which are equally spaced in a log-frequency scale.

'Pitch' simply defines sounds with no specific frequency information; the significant factor is whether they are the same or different. In musical terms a note describes a pitch with a specific frequencies that correspond to those of the chromatic scale in the Western tonal system, as seen in the table below.

Note name	C (Middle C)	C#	D	D#	E	F	F#	G	G#	A	A#	B
Frequency Hz	262	277	294	310	330	349	370	392	415	440	466	494

“Musical activities are fun. Motivation and engagement are important for successful learning by young children. The pleasurable aspects of music-making and dancing mean that rhythmic co-ordination skills are likely to be learned almost as a by-product of emotional engagement and having a good time. ” Goswami 2012 - pg 12 (in original article) .

Teachers of young children in schools generally have an a priori assumption that music is a ‘good thing’ and that it helps socialisation and empathy between the children and carers. Children are exposed to music from computer games, television, video and CDs etc., for many hours a day and are familiar with popular cultural reference points – music for singing and dancing, and music that surrounds everyday life such as shopping and background to viewing film and television. The vast majority of children engage with all of these stimuli in a positive way. Even though the performance of young children might not reach a level where they are accurate in their reproduction of songs or complex rhythms, they certainly are aware of the complexities associated with, rhythm, pitch, timbre, musical structure and even harmony from infancy.

In the first part of this section I look to establish the criteria on which the testing protocol depends:- what can we expect of the young participants? Is there sufficient stability in their musical performance that allows for meaningful comparisons to be made with their phonological skill acquisition?

There are two distinct areas of research that shed light onto the musical developmental of young children. First the development of their skills:- how they gradually refine their rhythmic and pitch performance, allowing them to take part within the music of their culture, and secondly how they are able to achieve these skills, through increased musical perception. Musical perception being the interdisciplinary approach to understanding the mental processes that support musical skills and behaviours, including comprehension, memory, attention, and performance.

An understanding of a child’s developmental progress in musical skills has been achieved by looking at the results from both musical aptitude tests

and large scale observational studies:- what can the children do (or perform) at various stages of their development from the earliest pre-natal responses to the ability to play an instrument or sing in tune? (See Table 2.2.2.) These responses are coloured by the cultural context and environment in which the child is nurtured. The findings from these studies are important, particularly from an education perspective, because they facilitate the ability of teachers and carers to devise an appropriate curriculum based on the age and ability of a child. In the formulation of this research the results of such studies provided me with the necessary reference points to help devise the musical stimuli that 4 to 5 year-old children would best respond and enjoy when participating in the data collection. Many past researchers into musical skill acquisition have often failed to inquire into the fundamental cognitive development that underlies the child's musical development, such as the ability to perceive the beat or the metrical structure which allows for repetition and easy comprehension of the way a piece of music is constructed, or even the biological functions that allow the child to sing and match their pitch to others. This section is divided into two areas:- first – the emergence of musical skill acquisition, and second – the emergence of musical perception skills. Both aspects are explored because they were both important in the development of the research paradigm used in the study.

2.2.1 The Development of Rhythm Skills in infancy and the pre-school child

Between 12 and 36 months of age children begin to engage in spontaneous musical activities (Trehub & Hannon, 2006). In 'The Musical Experience of the Pre-School Child' (1976) by Helmut Moog, he observed that young children in their second year still responded to the 'sensory impression' of the sound of music alongside its rhythm. He thought that this was the 'heart of musical experience' (p. 86). His study, involving 500 children, observed that children's first responses to music were through movement at around the age of 6 months. He reported that movements often involved the entire body and were described as rhythmical because of their repetitiveness, but they did not necessarily synchronize with the musical sounds. After the age of 1 the movement responses decreased, but increased

in their variety, and somewhere between the ages of 18 months and 2 years the children begin to “*match their movements to the rhythm of the music*”, but only for short periods. Moog also observed that shortly after children were able to make movement responses to music they began to make vocal responses which he referred to as musical ‘babble’. The first babbling songs lacked rhythmic structure and bore “*no resemblance to what is sung or played to them*”(p. 62). He, however, proposed that the child clearly related to the fascination of the sound itself and the pleasure of beginning to control sound. Between the ages of 1 and 2 years, children began to imitate songs and Moog found that children first produced words, then rhythm, and then pitch. About 16% of the children, however, began imitating rhythm and pitch without words and began including words between the ages of 2 and 3. By the age of 2.5, about 22% of children “sang” just words and rhythm; but by 3 80% imitated words, rhythm, and pitch. About 50% of 3-year-olds imitated entire songs. He felt that this indicated that, while the ability to sing and to move rhythmically to music begins to emerge before the age of 2 years, the ability to coordinate words, rhythm, and pitch in singing doesn’t begin to emerge until around the age of 2.5 years.

Table 2.2.2 Rhythm Skills – progression from infancy to year 5 in Gooding and Standley (2011)

General characteristics	Research suggests that the developmental sequence in rhythmic concepts is as follows: beat, rhythm patterns, meter, with meter developing around age 9 (Hargreaves & Zimmerman, 1992)
Infancy: 0–12 months	Infants can recognize changes in simple rhythms at 5 months (Gembris, 2006) Infants can detect changes in tempo (McPherson, 2006)
Infancy/early childhood: 1–2 years (12–35 months)	1- to 2-year-olds can match the rhythm of a model (Miyamoto, 2007) □ A regular meter in singing becomes noticeable during the second year (Gembris, 2006) 12-month-olds show adultlike, culture-specific responses to musical rhythms (Hannon, Trehub, & Purves, 2005) Encourage children to clap, play instruments, and move to the rhythm; marching to the beat will occur later (Rainbow, 1977)
Early childhood: 3–5 years	Most children become competent at perceiving and performing rhythms between the ages of 3 and 5 (Reifinger, 2006) Younger children prefer faster tempos (Reifinger, 2006) At age 3, children begin to create patterns through repetition (Miyamoto, 2007) □ 3-year-olds reproduce rhythms best vocally (Reifinger, 2006) 40% to 60% of 4-year-olds can keep a steady beat by clapping/tapping (Reifinger, 2006) Kindergartners are most accurate rhythmically when chanting (Loong & Lineburgh, 2000; Reifinger, 2006) Moving to music can facilitate rhythmic ability in motor skills execution (Teachout, n.d.); however, it is important to keep clapping and movement activities simple (Miyamoto, 2007) Performing rhythms vocally is easier for 3- to 4-year-olds, so voice should be used to teach rhythms (Gembris, 2006)

Moog found that between the ages of 3 and 5.5 years – old about 50%

of children continued to make spontaneous movement responses to music, but the variety of movement decreased. Between the ages of 4 and 6, movements increasingly matched the rhythm of the music and coordinated with the music for longer periods. Sims (1985) in her research with pre-school, primary and college aged teacher training students also found that 3 to 5-year-olds' rhythmic movement increased with age. Movements were rhythmical 22.49% of the time with 3-year-olds, 61.97% with 4-year-olds, and 73.86% with 5-year-olds. Rhythmic movements corresponded to the beat almost three times as often with the 5-year-olds as with the 3- and 4-year-olds, indicating that most children become competent in moving rhythmically to music between the third and fifth years of life.

Rainbow (1981) assessed 3- and 4-year-old children's ability to keep a steady beat and to echo rhythmic patterns. To perform beats or rhythms, a vocal response mode was the easiest for 3-year olds, 50% of whom could successfully perform the tasks. Only 10–14% were successful when clapping and tapping. Marching to the beat and echo-clapping a rhythmic pattern without vocalization were the most difficult tasks. Vocal responses were performed successfully by 70–90% of 4-year-olds. Only 40–60% of these children could keep a steady beat by clapping or using rhythm sticks, and 30–40% could echo rhythm patterns by clapping. Marching to the beat was still very difficult and was performed successfully by only 18–20% of the 4 year-old children. Rainbow believed that children needed to practice gross-motor skills, but he also concluded that using vocal responses and singing might be the most effective way to ensure success when beat and rhythm performance skills are first emerging.

2.2.2 The Development of Pitch in infants and pre-school children.

Bridger (1961) found in his study of 50 infants that when they were as young as 5 days old they could discriminate fairly fine differences in frequency. The varying frequencies of tones played to the babies produced both physical movements and changes in their heart rates. Infants showed a perceptual bias for high-pitches at around 6 months of age. In a ground breaking study reported in 1985 Eimas also reported the remarkable abilities of new-born children to discriminate accurately the sounds and characteristics

of phoneme onsets, such as an ability to differentiate between the sounds of ‘Bah’ and ‘Dah’ or ‘Maw’ and ‘Bah’. They concluded that this ability to finely discriminate such complex acoustic signals was innate, and the child is born with a perceptual mechanism that is tuned to the properties of speech. In another study, Olsho (1984) compared the ability of 18 infants from 5 to 8 months of age and adults to distinguish between high and low pitches. The task consisted in the presentation of a series of tones between 250 and 8000 Hz in either ascending or descending order. The infants were taught to make a head-turn whenever they heard a sound change. While the adults performance was equivalent for both low and high pitches, the infants performed better when the discrimination involved high pitches.

<i>Table 2.2.3</i>	<i>Pitch progression from infancy to year 5 in Gooding and Standley (2011)</i>
Infancy: 0–12 months	<p>Infants respond more to consonant pitches (McPherson, 2006)</p> <p>Infants are sensitive to pitch and timbre, and infants actually perceive small pitch differences better than adults (Gembris, 2006)</p> <p>Infants can detect melody changes and transposition around 6 months (Gembris, 2006)</p> <p>Infants can match pitch on single tones between 4 and 6 months (Miyamoto, 2007)</p> <p>Infants group patterns based on similarity in pitch (McPherson, 2006)</p> <p>Melodic contour appears to be the important melodic element (Hargreaves & Zimmerman, 1992)</p> <p>Use consonant music (Trehub & Hannon, 2006)</p>
Infancy/early childhood: 1–2 years (12–35 months)	<p>Children can approximate the pitch of a singing model (Miyamoto, 2007)</p> <p>Toddlers do not sing in tune consistently (<i>Encyclopedia of Childhood and Adolescence</i>, 2001)</p> <p>From about 12 months of age on, infants show culture-specific responses to some musical elements (Trehub & Hannon, 2006)</p>
Early childhood: 3–5 years	<p>Children as young as 3 years can nonverbally express their understanding of pitch-related elements (Miyamoto, 2007)</p> <p>From 4 to 5 years, children develop the ability to match pitch more consistently, although tonality is sometimes unstable (Miyamoto, 2007)</p> <p>Children between the ages of 3 and 5 respond more accurately on pitch-related tasks using nonverbal means such as tactile and visual modes (Miyamoto, 2007)</p>

Infants are not only sensitive to isolated pitches, but are also attentive to pitch contour i.e. the direction of pitches in a sequence. This almost certainly derives from the auditory experiences of the child in the womb and at birth. The way parents speak to their infants is a forms of speech (e.g., adult directed speech), and is known as "motherese", "baby talk." or infant directed speech (Femald, 1985; Femald & Kuhl, 1987; Trainor, Austin &

Desjardins, 2000). Motherese is generally higher in pitch, slower in tempo, linguistically simpler, more rhythmic, and is more exaggerated than adult directed speech (Femald, 1985, 1989; Trehub, Trainor & Unyk, 1993). Different pitch contours found in motherese ascribe different meanings and elicit different responses from infants (Femald, 1985). Bell-shaped contours (down-up-down) for example, are generally used to capture infant attention (Femald, 1989), while sustained and falling contours (down-down) are often used to calm and soothe infants (Papousek, 1991).

Researchers have also investigated the area of pitch matching. Kessen, Levine, and Wendrich (1979) found that pitch matching in infants between 3 and 6 months of age was attainable through training sessions that first used natural vocalizations of the infant stimulated by the mother, followed by vocal interchange between the infant and the experimenter. These vocal interchanges consisted of the introduction of a stimulus pitch within the determined pitch range of the baby, whereby every vocalization by the infant was answered with the stimulus pitch sung on “ah.” Pitch matching was deemed successful when the infant successfully matched the stimulus pitch five or more times. The notes of D, F, and A above middle C were used based on preliminary observations that these tones fell within the baby’s normally occurring range of produced sounds.

Wendrich (1981) revealed that pitch matching ability can be lost. After an interval of three years from the 1979 study by Kessen et al., children from the initial study were reassembled. Using exactly the same testing protocol the research found that the consistent pitch imitation observed at 6 months had become inconsistent at 3.5 years. It was concluded that the loss of pitch-matching ability was due to a lack of practice and experience. Welch (2001) has demonstrated that conservation of pitch is only achieved for some children above 7 years of age, and states, like Wendrick, that it depends on practice and experience. This phenomenon can explain the reasons why 4 year-old children often have poor performance skills in relation to their ability to sing in tune, even though the studies with infants indicate that the young child has a good perception of pitch.

Sloboda (1985) reported that prior research had shown that after learning a new folk song, four-year-olds could not maintain a steady beat

while singing it on their own. This would suggest that some children find it difficult to focus on both words, rhythm and pitch at the same time. They can be accurate in rhythm or pitch, but not necessarily at the same time.

These findings are supported by Moog (1976) who observed that a characteristic of this age is the ability to sing the words and match the rhythm, but only sing with an approximate stability of pitch.

The results from this study also match these findings. Out of the 192 children only 9% could sing 'Twinkle, Twinkle' accurately. 29% had no sense of pitch at all – 40% were 'modulating'⁹ singers and were just beginning to acquire a sense that the melody went up and down, and 22% were attempting accurate pitch. The children were tested individually and sang along to a pre-recorded backing track with an adult. Even though the pitch was age appropriate (C4 – A4 / 262 Hz – 440 Hz) as stated above 29% made no apparent effort to change pitch – they sang to a monotone. However they were rhythmically quite accurate even when the music they sang changed speeds. They seemed to have a good mental representation of the songs, but their performance did not reflect this (Miyamoto (2007 - See table 2.2.3). A possible explanation for the relatively poor performance of this group of children perhaps comes from the experience of the children in their home environment. In several schools within this survey I was able to meet and run sessions for the children and their parents before they entered pre-school. With very few exceptions the parents were reluctant singers and were embarrassed to sing to their children. Welch (2005) considers early experience as the most significant factor in being able to sing accurately. Even though the children sang 'out of tune' this didn't stop them trying to perform with enthusiasm and conviction.

The data gleaned from musical aptitude tests and observational studies, although of considerable value gives us no real understanding of how the child comes to be able to discriminate or move rhythmically to the music. Indeed the scores from aptitude tests often gave a very poor account of a child's suitability to play an instrument, because they give no data that can

⁹ (Flowers & Dunne-Sousa, 1990) used this term to indicate that the children's singing followed the correct contours of a song but were not sufficiently accurate to be able to say they could match the original song.

account for the child's learning styles. For example, a child who has a very high score and an excellent auditory response to the tests might find that the noises made as they learn to play the instrument are too 'uncomfortable', and they give up learning very quickly. Hallam (2006) suggests that the reasons for this are that ability tests, particularly those that are used to assess suitability to play an instrument do not take into account motivation or commitment.

2.2.3 The development and measurement of musical perception

Music psychologists were unhappy with the nature and limited application of the musical aptitude tests, because they failed to give any insight into creative achievement in music, or indeed the underlying musical perception, developed a different kind of research model. Davies (1978), for example, suggested that aptitude tests should assess musical reasoning and emotional connectivity to music. In consequence a further group of observational studies were developed to discover what the child understood whilst 'composing' or playing with musical ideas. These were largely in line with the developmental theories of Piaget. Piaget (1951) noted that play in very early childhood is characterised by the sheer pleasure of exploring and mastering the environment. He calls this "*a feeling of virtuosity or power*". The handling of voices and instruments, the development of ensemble skills, the use of notations, delight in the virtuosity of others, are obvious elements of mastery. A number of investigators adapted the 'Piagian' stages of development to demonstrate growth in musical abilities and perception (Swanwick and Tillmann (1986) Campbell, 1991; Gardner, 1973, 1993; Serafine, 1988; Zimmerman, 1984, 1986, Hallam, 1998).

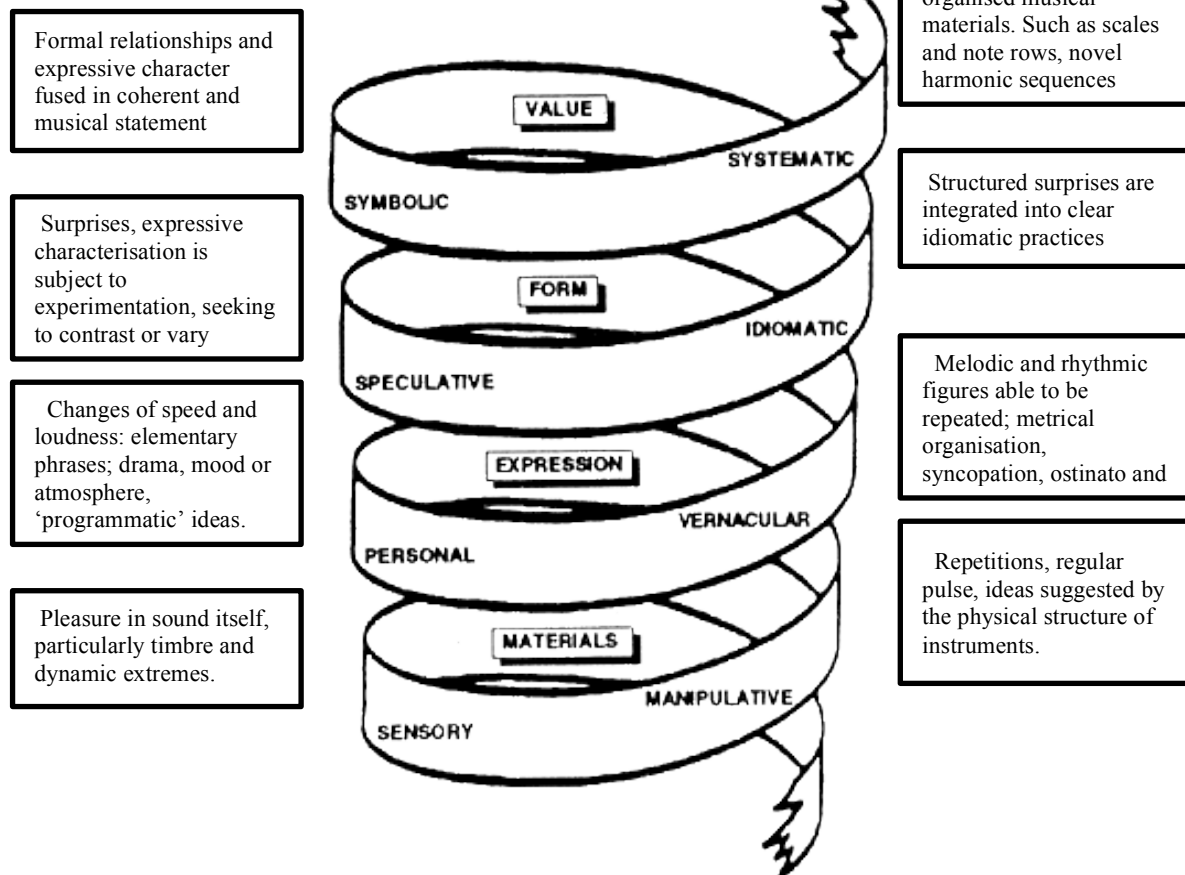
Initially most early musical activities are driven by a desire to see how things work in both a physical and aural way and musical activities are often connected to sound and timbre exploration – such as picking up a maracas and shaking it to see how it sounds (Miyamoto, 2007; Swanwick & Tillman, 1986). Whilst the young children enjoy playing simple percussion instruments and participating in vocal play they begin to develop basic musical abilities such as the ability to coordinate words, rhythm, and pitch

when singing (Gembris, 2006; Reifinger, 2006).

These theories are well expressed in the spiral diagram developed by Swanwick and Tillman (Figure 2.2.1) after they had investigated the changing nature and development of children's compositions. The diagram is, as was intended by the authors, a useful tool for educators, as it shows what a child might be capable of at a given point in their musical development and perception. Typically the research using such tools as the spiral diagram shows that children are able to perceive and have a far greater understanding of the music around them than is shown in their performances. This is exemplified in a study with 20 11–12 year-old Brazilian children (Swanwick and França 1999). Franca compared their understanding and their performance on the piano of three of their own compositions. She found that their perception of what they wanted the pieces to sound like far outweighed their ability to perform the pieces.

Figure 2.2.1

The Developmental Spiral (Swanwick & Tillman 1986)



The Development of Musical Perception in Infancy

Musical perception is very much in evidence in infancy, and Cross (2003) coined the term 'proto – musical behaviour' for this developmental stage in which we begin to see the emerging musicality that is later exhibited in the pre-school child. The child is 'primed' for music and yet their developing skills associated with music are always developed in conjunction with other skills, both social and biological.

Infant musical perception develops through parental musical involvement, as well as through the imitation of responses of other children. During infancy, children learn through the process of cause and effect to process sounds, move rhythmically, and use their singing voices (Standley, 2003; Warrenner, 1985).

Trehub and her colleagues (Trehub, Schellenberg & Hill, 1997; Trehub, 2003; Trehub and Hannon, 2006) have demonstrated that at six months

infants are 'rather capable listeners' and are sensitive to melodic contours. They experience as 'the same' melodies that share the same contour or pattern of ups-and-downs, even though the pitches might have changed. They have demonstrated that the infant possesses strong biological predispositions to respond to the musical features of the sounds they encounter. Even younger infants show a capacity for music. Mechthild Papousek (1996) showed that infants can display a range of 'proto-musical behaviours' in their interactions with their caregivers, using rhythm and pitch in a musical way. These proto-musical behaviours consist not only of listening to sounds but also of producing them and actively moving while doing so:-

“regular synchronization of vocal and kinesthetic patterns provides the infant with multimodal sensory information including tactile, kinesthetic and visual information”. pg 100.

Papoušek (1996) did not see musical development as being an independent construct, but as part of the development of speech and communication.

“speech, as a uniquely human form of communication, represents an unusually effective means of biological adaptation” Papousek - pg 38.

Papoušek proposed that speech-related and musical sounds are partly learnt in the infant's social environment, and Papoušek and Papoušek (1982) demonstrated how parents 'scaffold' the infant's vocal behaviour towards different levels of expertise. By the use of videotape to record the mother and baby interaction the Papouseks and their teams showed the build up of the infant/child relationship, and the constant interplay between the two. The exaggerated melodic contours found in adult-directed-to-infant-speech found in the recordings seemed to show that parental intuitive behaviour guides their babies' musical beginnings (Papousek 1996). Melodic elements therefore have not only a special attraction for infants as audible stimuli, but also form the characteristic basis of their own vocal utterances (Wermke, & Mende, 2009).

“The long developmental journey from the earliest emotionally loaded utterances of an infant to the fully developed language of an adult effectively begins at that point when feeling and need are conveyed to another via melody” Wermke, & Mende (2011) - pg 910.

The research into infants' musicality as a social tool is also exemplified in the work of Trevarthen (1999) but his work has focused perhaps more on the rhythmic and temporal elements of the 'Infant Directed Speech' rather than the pitch based emphasis found in the work of Wermke and Mende. His investigations of talk, singing and other rhythmic games with infants show that the general features of interactive musicality are displayed in the anticipatory movements and emotions that develop between infants and their caregivers. His research adds strength to the argument that a child comprehends the inherent rhythmicity of sounds around them and has a rhythmic time sense, which is able to detect regularities in musical elements, and is sensitive towards the acoustic elements of the qualities of the human voice, and the ability to perceive 'narrative' structures in vocal or musical performances. He concludes that musicality precedes and underlies language in the life of a child because parents reinforce the musical aspects of early vocalizations by repetition of the infant's prosodic utterances and, hopefully, by singing songs and lullabies. Gradually, vocal/musical play gives rise to speech and words. Early musicality thus encapsulates the interaction between biological predispositions and the social world.

Cross (2003) writes that music, or proto-musical activity, *"provides for a child a medium for the gestation of a capacity for social interaction, a risk-free space for the exploration of social behaviour that can sustain otherwise potentially risky action and transaction"*. pg 7.

2.2.4 Perception of Music as a 'whole' in the pre-school child

According to Meyer (1973), the ability to process rhythm, pitch, and melody involves perceiving coherent patterns of tones over time thus allowing humans to perceive music. One can now express these intuitions in a more scientific way and say that because the brain combines stimulus elements that are perceived simultaneously and in succession to form a coherent, perceptual structure the music is perceived as a "whole" unit (Krumhansl, 1990; Neuhaus & Knösche, 2006). This is a result of the ability to recognise patterns in a sequence of separate tones that is part of the structure of the piece of music. The structure allows a person to develop expectations regarding the types of patterns that might come next in the music

(Radocy & Boyle, 2003).

Krumhansl (2000) in her review of the literature on the significance of rhythm and pitch concludes that *“the perception and cognition of a piece of music reflects how the music is structured”*. This builds on the observational studies of Serafine, 1988; Davidson & Scripp, 1988; Bamberger, 1999 and Swanwick, 1999.

“‘tones’ are heard as ‘tunes’” (Swanwick, 1999)

and tunes are something that can be shared and perceived by others in a social and cultural environment.

The perception of structure is defined by the culture and is in place at a very early stage (Hannon and Trehub; 2005, Drake 1998). When the child reaches pre-school age one can observe more readily their perception of the music they hear because the internal processes of the infant are now exhibited externally – we can hear how they are singing and can track the slow maturation from melodic contours, with their variable accuracy, to the finished song. We can track how accurately they can tap or dance along to a piece of instrumental music. We can also glimpse their perception of what they are hearing and trying to achieve by looking, amongst other things, at their own visual representations of their musical experiences; singing, playing instruments and compositions. Davidson et al (1985; 1988; 1994) and Jeanne Bamberger (1980) showed that young children have an holistic perception of song which incorporates melody, rhythm and words.

Davidson insists that to view musical ability based on the ability to discriminate individual sounds from one another is incorrect. In a series of longitudinal studies Davidson was able to confirm the findings of earlier studies (Moorehead and Pond (1941) and Shuter-Dyson (1961) that had observed that children’s early efforts at singing were not based on an ability to match accurately a series of interconnected musical pitches (intervals) but came from a growth of understanding about the overall shape of a short melodic ‘contour’. He states emphatically that:-

“Children’s early ‘songsinging’ simply does not depend on linking of fixed pitches or key structures”

but must arise from a perception of unfolding motion within a melody. This was confirmed by later research by Platinga & Trainor (2005) that showed

that even 6 month-old infants have perception of the whole piece rather than isolated fragments when listening to a folk melody. Davidson further refined this argument after systematically observing 78 children aged 1 – 6 over a 6-year period. He then was able to suggest that the concept of musical ‘contour’, which conveys the figurative shape of the melody but not necessarily an accurate pitch, needed to be placed within a recognition of levels of mental organisation which he termed a ‘contour scheme’ which allowed the child to contextualise individual contours in relationship to others (Harvard Project Zero – Davidson 1985). Another longitudinal study tracked 9 children from birth for 5 years, commencing just after their first birthday. The findings of the sample were replicated with a further 69 children in a cross-sectional study who were matched by age and socio-economic background. During the course of the study it was possible to analyse the development of the ‘tonal contours’ and see that whilst the child slowly gained more accuracy of pitch, they seemed always to have the phrase structure in mind even when the song was sung inaccurately.

By the age of 3 the rhythmic nature of these elementary phrase structures was often linked to words, which were replicated with increased consistency (Davidson and Colley. 1987).

Davidson together with Jeanne Bamberger then looked further into the children’s perception of musical contours, and how they might give a greater insight into their perception of musical structure, which combines melody, rhythm and harmony and give insight into the child’s developing ‘musical intelligence’. Davidson and Bamberger confirmed this as they looked at visual representations of children’s songs. Bamberger analysed 4 and 5 year-old children’s figurative representations of simple songs and noted that they represented simple rhythmic patterns. As the child listened to the songs they drew representations of fast and slow notes as they occurred. Her principle conclusions from this early work suggested that the child could organise their listening into small units, which she later termed ‘tuneblocks’.

“Concentrating on the smallest levels of musical detail – individual pitches, metric values, intervals and basic notation these approaches actually impede progress.Working with ‘chunks’ of musical

information students learn to create a structural framework for their musical intuitions” ‘Developing Musical Intuitions’ - introduction (1999).

The concept of listening and dividing the whole experience into ‘chunks’ seems to carry on into adulthood. In a study by Tillman et al (1996) the researchers played recorded performances of piano pieces of Bach, Mozart and Schonberg to 40 adult ‘non-musicians’. The music was segmented into short chunks of six seconds on average. These chunks were linked either in a forward order or backward order. In the latter version, the global structure of the pieces was effectively destroyed, but the superficial features and the local structures inside the chunks were unaltered. When the participants listened to both the Bach and the Mozart pieces, playing the chunks in a forward or backward order did not affect their feeling of coherence. The researchers concluded that short chunks contain enough information to define the expressive qualities in the music for non-musician listeners.

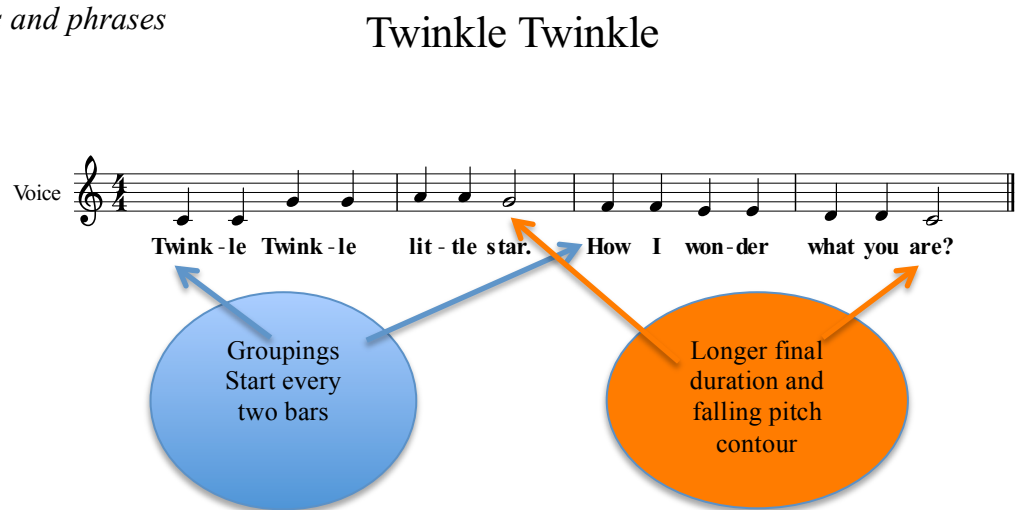
The young child’s experience of music is formed not only from an amalgam of varying purely musical elements, but research shows that they even find it difficult to differentiate between music with or without lyrics.

Both Crowder (1990) and Serafine et al (1984; 1986) demonstrated that even adult listeners simply cannot “ignore” the lyrics in a song despite explicit instructions to attend only to the melody. Recognition performance is better in original melody-lyrics contexts compared to melodies with nonsense lyrics. In a study by Morrongiello (1990) she showed that 4-year-old children were more likely to identify two songs as the “same” if at least the words were the same, and as “not at all the same” if the words were different, regardless of melody congruency.

The inference from looking at these studies is that pre-school children are able to respond to music with multiple dimensions when the music seems to follow ‘the rules’ or principles. The example from Tillman and Bigand (1996) quoted above would seem to suggest that even if the music does not follow the expected structure, and musical phrases are deliberately manipulated to distort the original composers intentions the brain still has the capacity to interpret the music as if all the normal rules were in place.

Lerdahl and Jackendoff (1983) proposed that the psychological representation of a piece of music includes a hierarchical organization of groups called the ‘grouping structure’. The groups gradually combine together to form larger units. The grouping structures usually are rhythmic but they can be characterized by changes in loudness, timbre (spectral properties), pitch, and/or duration. We perceive individual auditory events as part of a larger pitch and rhythmic structure, as smaller units are grouped into larger and larger units in hierarchical structures (Krumhansl, 2000; Radocy & Boyle, 2003). We can see this process of grouping events emerges in infants as early as four months of age. A child shows a preference for listening to groups that end with a falling pitch contour and long final duration (Krumhansl & Jusczyk, 1990;¹⁰ irrespective of language and culture. (See Figure 2.2.2.)

*Figure 2.2.2 Twinkle Twinkle
Groupings and phrases*



In a subsequent study, Jusczyk & Krumhansl (1993) further examined infants' (N=120) preferences for naturally and unnaturally segmented musical phrases using several manipulations of the stimuli including reversed excerpts (i.e., played backwards). They found that infants not only preferred the naturally segmented excerpts, but also were attentive to musical phrase structures, using descending contours and changes in pitch duration (i.e.,

¹⁰ In this research with Japanese children the experiment looked at infants' sensitivity to clausal units in a mora-timed language.

slowing down) as indications of endings in musical phrases. (see Principle 1 in Table 2.3.1 below).

2.2.5 Implications for the research paradigm

In the résumé of children's skills in Tables 2.2.2 and 2.2.3 we can see that a normal developing child will be able to tap and sing along to music quite successfully. Even though their singing skills might not reflect their ability to perceive and perform the songs accurately, this should be no barrier to their ability to keep accurate time, indeed Reifinger (2006) suggests they will be much more accurate.

The literature tells us that there is a progression of musical skills and musical perceptual abilities which are not fully formed by the age of 5. The children, however, generally love to interact with music in its social and cultural context and tapping along to a beat or singing a song are all experiences they can explore with pleasure and some levels of expertise. The literature tells us that these skills are developed from infancy and some of the really sophisticated qualities of music, such as the ability to detect ambiguous rhythms and chord progressions and the underlying structure are all in place by the age of 4 to 5-years-old. (Koelsch, 2008). The 4-year-old child is already quite a competent musician and so we can track their rhythmic competence whilst they drum or sing to culturally appropriate music that has predictable form and structure.

In this research paradigm I further explore whether the children are most accurate in synchronising to a beat, and whether words are a distractor or actually help the children to keep in time. The literature discussed in this section does not give us an indication of whether certain speeds, or pulse rates give preferential performance. Neither does it give us an indication of whether the children would synchronise most accurately to a stimuli, with minimum distractions, such as a metronome beat, especially since the literature would suggest that music that has exciting sounds will galvanise interest, and by implication result in more intensive listening and accuracy of performance. (see Swanwick and Tillman diagram – the children take *“Pleasure in sound itself, particularly timbre and dynamic extremes.”*)

The testing protocol therefore takes this into consideration and compares the results of children's ability to synchronise with a variety of musical stimuli. We therefore need to explore how they can do this, because the children's ability to synchronise to music is dependent not only on the social context or familiarity with the kind of music they hear, but how their brain actually processes the information that allows them to engage in the activity in the first place. This is dependent on their temporal and rhythmic processing ability.

2.3 Temporal and Rhythmic Processing

Table 2.3.1 Five Temporal processing Principles (Drake & Bertrand 2003)¹¹

Principle 1

Researchers have studied sensitivity to musical phrase endings as an indicator of temporal segmentation to understand how people perceive the ending of one auditory Gestalt and the beginning of the next (Krumhansl, 2000; Krumhansl & Jusczyk, 1990). Bertrand (1999) studied segmentation in 4- to 12- year-old children with and without musical training. Results showed that children as young as four years old segmented tonal sequences according to musical elements, such as pitch change and pause duration. Participants also segmented an auditory sequence after a longer note, a pause, or a large pitch difference. Children showed a small improvement with age and musical training, but their progress may be due to possessing better skills related to the task, such as improved ability to sustain attention.

Principle 2

The second temporal processing principle states humans have a predisposition towards regular sequences, meaning sequences with a steady beat and tempo regularity. Humans do not encode precise durations of individual sounds. Instead, they compare the duration of a sound as it relates to other preceding sounds through relative processing. Thus, auditory stimuli are coded as being the same or different and longer or shorter than each other.

In a study investigating the effect of rhythmic regularity on temporal processing, Drake and Gerard (1989) tested five- and seven-year-old children using regular and irregular rhythmic reproduction tasks. Participants showed non-significantly better performance at reproducing regular rhythms than irregular ones. Drake, Jones, and Baruch (2000) have also examined the effect of temporal regularity by examining listeners' ability to discriminate small differences in tempo and to reproduce rhythms. Results indicated that four-year-old children could detect small tempo changes during rhythmic sequences with a steady beat, but showed difficulty during irregular sequences lacking a steady pulse.

Principle 3

Humans actively seek regularity in temporal sequences (Drake & Bertrand, 2003). Listeners show a predisposition toward finding a regular beat or pulse in a given piece of music. Thus, the pulse serves as a framework to organize the musical events in time. Children prefer simple meters with beats that are isochronous, or have equal durations between beats. Four- to six-year-old children can tap in synchrony with the underlying beat of a piece of classical music which shows their ability to detect and synchronize a movement to a musical pulse (Drake et al., 2000).

¹¹ This synopsis is adapted from The five principles of Drake and Bertrand found in The role of Music Perception in Predicting Phonological awareness in Five - and Six-Year – Old Children. Lathroum. L.M (2011).

Principle 4

Auditory temporal processing involves the rate at which temporal information is processed (Drake & Bertrand, 2003). Humans, from birth through adulthood, show maximum sensitivity to temporal changes when beats are 600 ms apart (Baruch & Drake, 1997). The zone of optimal processing for temporal information ranges from 300 to 800 ms inter-onset interval (IOI), that is, adults show greater sensitivity to tempo changes or temporal irregularities if beats are 300 to 800 ms apart (Drake & Bertrand, 2003). Children between four and ten years of age showed the same zone of optimal temporal processing, centered at 600 ms. When compared to four-year-old children, ten-year-old children demonstrated a wider range of sensitivity for beats occurring at a slower or faster rate than every 600 ms. By age ten, children showed the same zone of optimal processing as adults, ranging from 300 to 800 ms (Drake et al., 2000).

Principle 5

Auditory temporal processing principle revolves around the human predisposition towards perceiving durations of sounds in simple ratios of two to one (Drake & Bertrand, 2003). Listeners tend to perceive sounds as being twice as long or twice as short as preceding sounds (Clarke, 1987; Parncutt, 1994). This principle leads to binary ratios being more predominant than ternary or more complex ratios. Five-year-old children show the ability to discriminate and reproduce short rhythms based on 2:1 ratios, but not 3:1 ratios (Drake, 1993a; 1993b). When asked to reproduce rhythms with complex ratios, five- and seven-year-old children tend to make errors due to a tendency to simplify rhythms into 2:1 ratios (Drake & Gerard, 1989).

By using the kind of songs and music that the children are familiar with in music research trials Drake (2003) proposed that they would respond and interact positively to the tasks. Tasks using real music and sounds can still discriminate the important elements under scrutiny (Honing 2009) and once again this can be traced back to early experiences. In the 1990 study Krumhansl & Jusczyk had exposed twenty-four 4- and 6-month-old infants to natural and unnatural musical excerpts taken from 16 Mozart minuets (i.e., excerpts with pauses inserted at the end and in the middle of a musical phrase, respectively), and measured their attentive listening for each type of excerpt. As it occurs with speech (see Jusczyk et al., 1992), infants in their study attended significantly longer to naturally segmented than to unnaturally segmented excerpts of music. This is consistent with Drake's second principle, as is the need for the human being to search for regularity and rhythmic structures that she explores in the third principle.

Thaut (2005) suggests that it is rhythmic grouping that can best express musical 'syntax'. The rhythmic and metrical features within the

music rather than the melodic content seem to underlie the ability to predict, process and remember musical events.

“ Rhythm, in the narrower sense, refers to explicit divisions of time or space into intervallic time systems, recurrent and often (but not always) characterised by periodicity. Components of musical time divisions such as pulses, beats and meter systems are relevant in this understanding of rhythm” Thaut 2005 - pg 4.

The tempo, or pulse rate, and the duration of the beats within the pulse rate are inextricably linked. In order to establish a tempo, or pulse rate, you need to be able to process the length or duration of each beat. A fast tempo will have a shorter inter-onset interval (IOI) between beats, and a slow tempo will have longer IOI's. A sense of rhythm not only includes the concepts of pulse rate and duration, but how the pulse rate is divided into subdivisions that provide a structure for making sense of the music – the ‘meter’

Rhythmic patterns are much more easily processed when they exhibit meter, that is the music is subdivided into smaller rhythmic units by placing accents on specific beats. For example, a waltz has a meter in which the basic beat is divided into units of three, in contrast to a march, where the basic beat is divided into units of two. These units then provide a form of structural building blocks which allow for *“better perceptual gestalts to emerge”* (Thaut 2005 pg 5).

In Table 2.3.2 London (2012) shows that the most significant factor in predictive qualities of music is not the groupings described by Lerdahl and Jackendoff but the meter, because it creates a continuous cycle of beats, whereas, theoretically, the groupings need not be continuous, and therefore are less effective in organizing the child's musical perception.

Table 2.3.2 Grouping and Metrical structures – London 2012 pg 6

Meter	Grouping
Endogenous Beats	Phenomenal Durations/IOIs
Beats organized into cyclical and stable measures; pattern repeats exactly and consistently	Durations/IOIs organized into groups which may or may repeat
Measures are continuous; no gaps within a measure	Groups are continuous; no gaps within a group
Measures are contiguous; no gaps between measures	Groups need not be contiguous; often gaps between groups
Measures involve at least two beats to establish a repeating cycle	A group may consist of a single duration or onset.
Metrical Accent stems from the listener's sense of the beat cycle and where it repeats	Grouping/rhythmic Accent stems from the physical properties of the sounds
Metrical Accent always at the head of a metrical cycle	Grouping Accent may occur anywhere within the group
Meter is strongly predictive	Grouping is weakly predictive

According to London 2012:-

“meter is a product of our dynamic interaction with patterns of sound events in the world; as such, it is best understood as a form of ‘entrainment’, our ability to synchronize a periodic aspect of our attention and/or behavior with rhythms present in the environment.” pg 5.

‘Entrainment’ or beat induction can be seen as a fundamental cognitive skill that is needed for the musical performance and listening (e.g., Patel, 2008; Honing, 2012). Entrainment refers not only to an ability to extract the main accents and stress in music and speech, but also to an ability to maintain a perception of pulse for future use. In affect we can hear a pulse in a rhythmic pattern while it might not even be explicitly there. In speech the pulse or accents might become quite ambiguous at times, but the brain can still assemble them with reference to the entrained beat, thus allowing the listener to predict and react to what will come next. The temporal organisation of the beats establishes order and, therefore, builds relationships in the perceptual process (Cross 2009) and this allows us to be able to synchronise body movements to a beat and engage in musical activities such as singing or dancing with others. This requires the human brain to process and respond to any changes in the pulse rate of the activity to maintain synchronisation. The brain needs to ‘entrain’ to both a fixed and changing pulse rate.

The ability to entrain to a beat is not only a product of listening to music within the social environment. Neither is it simply a matter of detecting a pulse rate and being able to tap or dance along to it. Entrainment allows us to make judgments about a continuous stream of beats, and see that some might be different – longer or shorter, louder or softer, or indeed if some are missing (Drake & Botte, 1993; Friberg & Sundberg, 1995; Repp, 2001). In other words, it allows us to detect both the meter and pulse within a stream of beats or notes even when some are not isochronous¹² This ability seems to be rooted in our biological functions that link listening to motor activity – the key areas of music making (Chen, Penhune, & Zatorre, 2008; Grahn & Brett, 2007; Zatorre, Chen & Penhune, 2007), and it therefore can be considered to be a fundamental cognitive mechanism that might well have contributed to the origins of music (Honing, 2011a; Honing et al., 2009).

2.3.1 The development of temporal processing in infancy and the pre-school child.

Recent empirical studies show that the ability to perceive beats is already active in newborns and young infants (Winkler & Honing et al., 2009; Zentner and Eerola, 2010) and then further modified within the social setting. In research by Honing (2009) sleeping new-borns were presented with 300 trials of a stimuli based on a rhythmic rock pattern in an ERP¹³ experiment. The infants were able to differentiate between the trials that were on the beat, and also where there were variations of pulse. The new-borns' responses were very similar to adults, and showed that beat perception is in place at birth.

The work of Trehub and others have shown that young infants are sensitive to rhythm and can perceive differences in rhythmic patterns (Chang & Trehub, 1977; Demany, McKenzie, & Vurpillot, 1977, Hannon, 2008) and this would also suggest that the necessary functions for perceiving a steady beat are in place, indeed Trehub suggests that most musical skills that are evident in infancy, well before they have obvious utility, can be considered

¹² A sequence of events is isochronous if the events occur regularly, or at equal time intervals.

¹³ ERP = Event-related potential, an electrophysiological response to an internal or external stimulus.

'predispositions for later musical perceptions' (2006, pg 3) such as beat perception and sensitivity to metrical groupings.

The infant's ability to process beats as a cognitive function is then further enhanced by their cultural experiences, transferred to the child by their parents and carers. This idea is supported by findings of multisensory interactions between movement and auditory rhythm in infants and adults. Specifically, when infants are bounced to an ambiguous rhythm (i.e. a rhythm without accents) in either a 'march' pattern (bounced on every second beat) or a 'waltz' pattern (bounced on every third beat), they show a subsequent preference for an auditory alone version of the rhythm with accents that match how they were bounced (i.e. every second or every third beat), even though they all heard the same ambiguous rhythm during the bouncing (Phillips-Silver and Trainor, 2005 & 2007). However, considerable cultural diversity characterizes temporal interval relations in music, with some cultures dividing time intervals into, for example, 11 beats. Those children and adults who have been raised to listen to Western music have considerable difficulty encoding rhythmic patterns from outside their culture. For example, Bulgarian and Macedonian adults exposed to Balkan music, which contains ratios consistent with both isochronous (i.e. 2:1 and 1:1) and non-isochronous (i.e. 3:2) meters, are equally good at detecting disruptions to isochronous and non-isochronous meters, whereas adults from North America only succeed with isochronous meters (Hannon and Trehub, 2005; Hannon 2012).

2.3.2 Synchronisation and entrainment to a musical stimuli

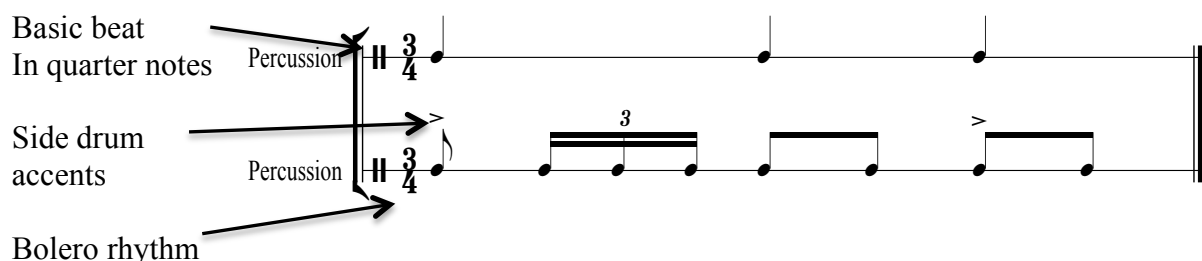
An isochronous piece of Western music has regularity and predictability, but within the milieu there has developed considerable complexity. Fully orchestrated music, with many complex interweaving rhythms and melody lines can still be rhythmically very "tight" or highly synchronised to the pulse rate and very young children are able to entrain to these complicated aural stimuli.

In a study concerning preferential tapping rates and synchronisation at different ages by Drake et al (2000) children between the ages of 4 and 10 and adults were given a series of tapping tasks one of which was to tap along to the first 30 bars of 'Bolero' by Ravel. These bars (measures) are in a strict 3/4

rhythm, but with a complex underlying metric division provided by the continuous syncopated drum rhythm played on the side drum (there is a much stronger accent on the third beat than would be normally expected). It is a measure of a side drummer's prowess to keep the core rhythm going for nearly 15 minutes. It is generally played at between 60 to 70 quarter note (crotchet) beats per minute. This corresponds to rates of between 1000ms and 860ms IOI, which the children, and indeed adults, normally find difficulty in tapping to. This particular piece of music is orchestrated to emphasise the accents at the continuous slower rate. The piece was chosen by the researchers because:-

“the multiple hierarchical time levels are redundantly marked in the acoustic structure by changes in intensity, relative timing, frequency, and timbre, and thus combined intensity and rhythmic cues co-vary systematically with the level in the time hierarchy.” pg 264.

Figure 2.3.1 Core Rhythmic side-drum pattern in Ravel's Bolero



Surprisingly the 4 - year - old children in the trials were able to tap along fairly accurately to this complex slow rhythmic music. There were no differences between the children aged between 4 and 10 year-old and adult response, irrespective of musical training. The various cohorts actually performed less well in another task where they had to tap along to an isochronous drumbeat with a strong metrical stress, again in triple time. The researchers speculated that young children have the capacity to tap along to complex (real) music because they are familiar with this kind of stimuli rather than with the musically 'decontextualized' sounds found in most tapping tests

that used computer generated tones. In line with the conclusions found in the Drake study I found that children also tapped with increased accuracy at the slower rates when they drummed to music. Both the results from the Drake study (2000) and those reported in this thesis suggest that a musical stimulus does give increased power to the children's ability to entrain at most rates, even the slowest, if the metre is strongly emphasised as suggested by the 'dynamic attending theory' (Jones and Boltz 1989, Large and Jones 1999, Repp, 2002c).

A long tradition of research exists on synchronization with simple metronome beats (e.g., Dunlap 1910; Fraisse et al. 1958; Woodrow 1932), but this research does not necessarily transfer to research where the participant needs to synchronise with a musical stimuli. The concept of a very regular and unchanging pulse rate in performed music is a relatively new phenomenon. It probably came about with the development of relatively affordable synthesisers and computer based music in the 1970's.¹⁴ With this kind of technology one could programme into the computer a mathematically formulated pulse beat, set at whatever speed you wanted. In live music performances there is always considerable flexibility in beat accuracy, sometimes deliberate, and sometimes not but the brain is able to take into consideration fluctuations of pulse, and synchronise with others – it has an 'error correction mechanism' built in (Bispham 2006; Clayton 2012).

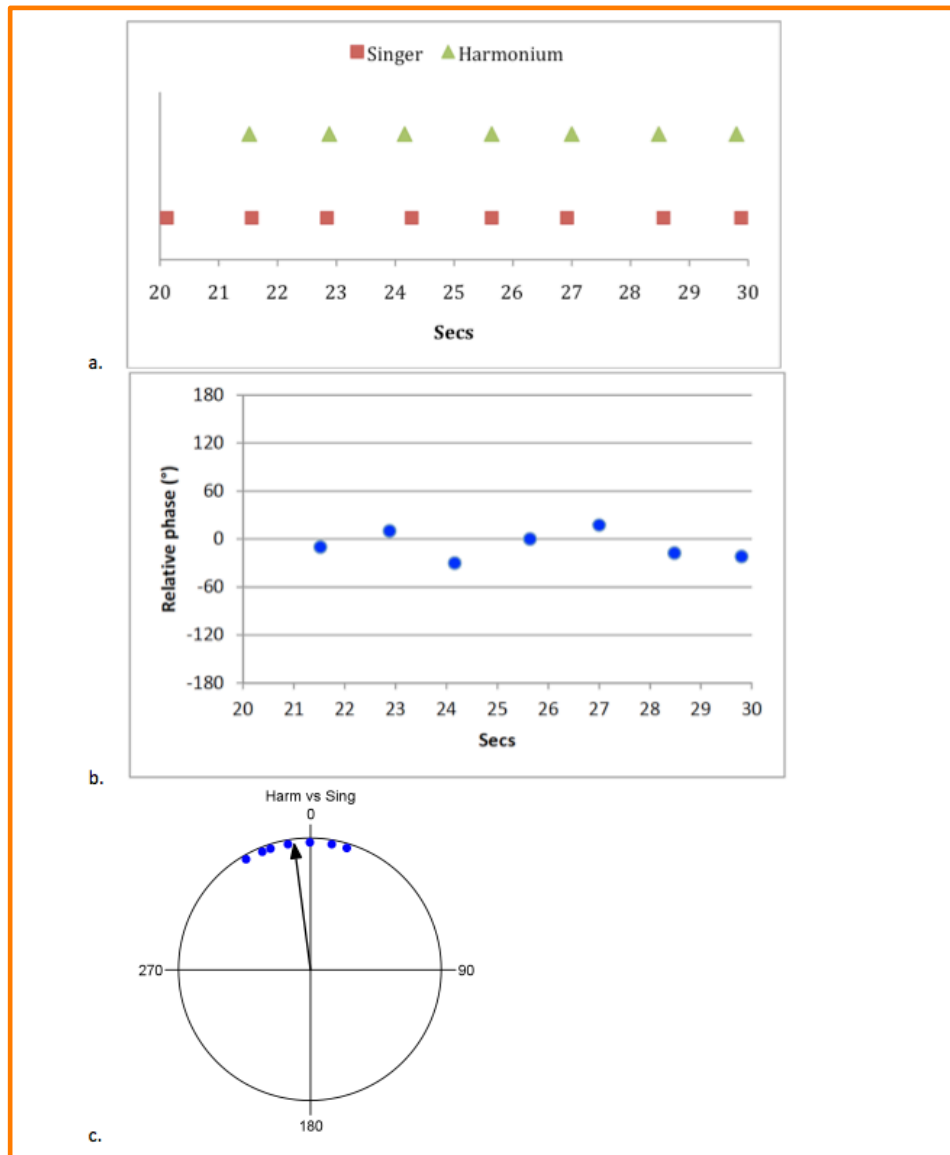
In Figure 2.3.2 we see a visual representation of a performance by Indian musicians – one playing the harmonium and the other singing. (Clayton 2012)

If the performance had been replicated by a computer programme it would be possible to make sure that both were exactly synchronized or in phase with each other. The real life situation is different. They are still connected, but slightly out of 'phase'. 'b' is a figurative representation of the way that one musician slightly anticipates the other, and 'c' shows this in terms of a circular statistical diagram with the arrow pointing slightly before the 0° line. (0 degrees is the point of perfect synchronization)

¹⁴ Switched-On Bach was a musical album by Wendy Carlos and Benjamin Folkmann released in 1968. It played a key role in popularizing classical music performed on electronic synthesizers, which had until then been relegated to experimental and "pop" music. This fostered a significant increase in interest in electronically rendered music in general, and the Moog synthesizer in particular.

(See Chapter 7 for full details of the circular statistical analysis)

Figure 2.3.2 A statistical analysis (both linear and circular) of a performance showing deviation and entrainment to a beat. (Clayton 2012).



The capacity to find a regular beat even when it is not always accurately presented in music is quite a sophisticated concept, but it is very common in all forms of music. Pulse rates can speed up or slow down according to the emotional context, sometimes by very small amounts. This phenomena is well reported in studies with adults (Large 2008; Large et al 2002) but I found that even children as young as 8 years- old children could distinguish when a regular rhythm is interrupted by a very small amount (Huss and Verney et al 2011).¹⁵

This of course requires the children or participant in the musical activity to be aware of a fixed isochronous beat. Once this is established the more accomplished musicians is perceived to be able to refer to this fixed pulse rate and change speed with reference to the original pulse – in other words they keep the pulse rate in mind and then deviate from it, knowing they can return to the original at will (Large and Palmer 2002; Madison and Merker 2002). Once regularity is perceived, the brain can tolerate small temporal perturbations. This same tendency is found in speech rhythms which are never isochronous, even though across languages there is generally a regularity; stressed syllables occurring on average every 500 ms, (Cutler, 2005; Arvaniti, 2009).

If a child or an adult can truly entrain to a beat then theoretically they should be able to maintain a sense of pulse after the music stops, and have a mental representation of an on-going beat that continues without the music or metronome stimuli. A rhythmic piece of music with strong metrical accents should provide the listener with a greater chance of on-going entrainment. However in the research for this PhD I found that the young children found maintaining a beat after the music had stopped was very difficult whether the stimuli was tapping to a metronome or to a piece of strongly metrical music. Whereas older normally developing children might improve with more experience the difficulty carries on in children with dyslexia (Thomson, 2008). In her research 48 10-year-old children (25 dyslexic and 23 typically developing) were given rhythmic metronome tasks at three rates (400ms,

¹⁵ In the test used in this study children had to say whether two rhythmic excerpts were the same or different. The musical excerpts were simply a two bar rhythm pitched to G using a simulated chime bar sound played at a pulse rate of 500ms. The differences between the two pieces were simply that one accented beat was made either 100 or 166 milliseconds longer on the second hearing.

500ms and 666ms). The tasks were in two conditions. The first was a beat alignment task with a metronome (the ‘paced’ condition), where the children simply tapped along to the sound of the beats. A second task was also given to the children where they had to continue tapping after the metronome had stopped (‘the ‘unpaced’ condition). The children found this second task very difficult. However, despite the complexity of the tasks the results were predictive of individual differences in phonological development, oral language development and reading development between normally developing children and the dyslexic cohort – the dyslexic children found tapping to the beat more difficult than the typically developing child.

When researching how accurate a child or adult can entrain to a musical beat the most widely used method is to measure how accurately they can tap or drum along to a piece of music or reproduce a rhythmic task, either by tapping along to a metronome or reproducing a pattern by clapping or drumming. However the longitudinal study of Rainbow (1981) noted that 3 to 4 year-old children were more rhythmically accurate when vocally chanting along to a rhythmic phrase than when asked to clap or step along to the rhythm. We therefore have to be circumspect when looking at the results of all rhythmic accuracy tests for differing age groups because the tasks and the expected outcomes in the research varies. A metronome task without any metrical emphasis will generally elicit a very different response from a task that requires the child to tap or march along to a piece of music or a song. A child’s ability to entrain to a beat at the age of 4 or 5 is still developing and they find some tasks easier than others. Serafine (1988) in her analysis of the developmental process maintained that the child’s first understanding of music was within an on-going, temporal context, rather than the perception of the physical entities of sounds (or silences).

“the principle characteristic of music is movement in time:- the exploration of simultaneous and successive events that embody points of arrival and stasis, points of departure and continuation, and a train of event to event similarities and transformation”. pg 69.

Serafine gave tasks to 168 participants divided into age groups. None of the tasks required formal musical training and participants with musical

training performed no better than those without training. The children were asked to find phrase boundaries in a 4 bar piece of music, where the melodic contour, harmony and rhythmic pattern suggested a new idea at the beginning the 3rd bar. The five year-old children were more successful at this task than in the other tasks where they had to note repetition and changing patterns within the music. By the age of 10 and 11 the children found all the tasks easy. Serafine therefore concluded that music cognition

“results from normal cognitive growth and everyday experience with music, and not from learning in a narrow sense”.

Culture-specific metrical knowledge develops throughout childhood. For example, studies of synchronized and spontaneous rhythmic tapping suggest that this ability improves and expands to slower tempos from toddlerhood through adulthood (McAuley, 2006, Bobin Begue, 2003). The first large-scale study of rhythmic entrainment in children was carried out by McAuley and colleagues in 2006. They studied tapping to a metronome beat in a cohort of 305 participants aged from 4 years to 95 years. Entrainment within the region of greatest pulse salience (60 – 150 bpm, or 1000 – 400 ms) was remarkably consistent in childhood, with temporal accuracy of tapping falling within 50 ms of the target rate on average between ages 4 – 12 years. Entrainment accuracy at the slowest rates (1000 ms and higher) was markedly poorer in the youngest children (age 4 – 5 years, for example this age group was almost 200 ms out of time on average when tapping to an 800 ms rate), but improved quickly at these slower rates (e.g., to around 50 ms for the 800 ms rate by age 6 to 7 years).

In the group of participants (n 192) children I tested for this PhD I found that the 4 to 5-year-old children found tapping to an IOI¹⁶ of 1000ms considerably more difficult than the faster IOI of 400 and 500ms. This could be because they acquire system-specific knowledge through ever increasing exposure to the music they hear.

Moelants (2002) collected data from 74042 pieces of music in a dance

¹⁶ IOI - Inter- Onset Interval of 1000ms = 1 beat per second = 60 bpm (beat per minute)
ISI – Interstimulus Interval is often substituted – and is fundamentally the same thing.
IRI – Inter response Intervals – same thing

style and discovered they were all within a very narrow tempo range, but focused particularly on 120bpm (IOI of 500ms). In his research he found that this corresponded to the preferred spontaneous tapping speed and also of a preferred walking speed. The research of McCauley (2006) on the variations of beat perception over a lifespan focused on tapping along to metronome beats, but without the advantage of computer aided technology earlier research focused on more child-centered activities that links more closely with the research of Moellants. In 1929 in a small scale study (n 29) Hulson (reported in Loong' 2000) found that the children matched their walking to music at a speed of 132 bpm and found that there was a high correspondence between children's ability to clap in time to music with their ability to walk or march in time. The corollary of this was reported in a study by Walters (1983) with 96 children. This study reported that a child will:-

“experience greater difficulty synchronizing with music as that music diverges in tempo from his/her personal walking tempo”. pg 85.

Vaughan's multi cultural study with children from Canada, England, Denmark , Columbia and Argentina (1981) found that all the children in the Kindergarten age range walked most accurately to a beat of 118.6 bpm. She asked the child to sing a previously taught song and then walk for 30 metres maintaining the pulse rate that they had just sung. Vaughan suggested that if a music educator

“starts with a tempo dictated by the children's own behavior then their ability to respond will increase dramatically” pg 99.

These studies have focused on synchronization and entrainment to musical beats. Other studies, particularly those looking for perceptual skills in both music and language, have looked at the child's ability to copy rhythmic fragments (Moritz 2007; Overy 2003).

In the field of pure musical perception citing the work of Zenatti (1976), Hargreaves (1986) reported that when four- and five-year-olds were asked to tap back the rhythms on 2-, 3-, or 4-note rhythm pattern samples in two trials, there was a marked improvement at the age of 4.8. Up to 4.8, children “who failed in the first trial showed significant improvement after

observing the experimenter tap the rhythm a second time. By the age of 4.9, however, 70 % of the first attempts were successful (p. 81). This difference in success rates in rhythm copying between 4 and almost-5 year olds may be partially due to 4-year-olds' difficulty in restraining the rapidity of their responses. Pouthas (1996) found that "certain 4.5 - year-olds are unable to refrain from responding too quickly. *"Their inter-response intervals are very short"* pg 132.

Drake (1993) found that the success of five-year-olds in copying short rhythm patterns greatly depended on whether the test pattern was binary or included ternary groups (i.e., patterns in which some of the notes were in groups of two versus three). Approximately 90% of the subjects could accurately copy simple binary patterns, but were only successful in copying about 20% of simple ternary patterns. They were successful on approximately 25% of complex binary patterns, and this dropped to approximately 15% of complex ternary patterns. Because the young subjects often respond without regard for the tempo in such tests, which often have fewer than 8 beats, they cannot give insight into rhythmic accuracy in terms of alignment to a beat or pulse and so this task was excluded from this PhD study.

2.3.3 Implications for the research paradigm

This resume of temporal processing shows that we would expect to see in normally developing 4 to 5 year-old children rhythmic skills that are well developed and becoming increasingly adaptable to take into account the variability of pulse that occurs when performing with others (Kirshner and Tomosello 2009). In their study of rhythmic entrainment via drumming in children aged 2.5, 3.5 and 4.5 years of age they demonstrated relatively accurate performance by these very young children (Kirschner & Tomasello, 2009). The children were required to synchronise their drumming with an external rate of either 400 ms or 600 ms. Children at all ages were within a median temporal accuracy of below 40 ms at the 400 ms rate, and below 50 ms for the 600 ms rate. Although language skills were not measured, children at all ages showed significantly more accurate entrainment when drumming with a social partner (drumming along with the experimenter rather than with a drum machine).

Most fundamental motor patterns are in place by the age of 5, setting the stage for increased musical motor abilities (Loong & Lineburgh, 2000) and so by this age we can track accuracy of the child's rhythmic perception, but even at this age some of these abilities are still rudimentary in nature and are often inconsistently demonstrated. However rhythmic matching, and beat alignment are generally performed much more accurately than pitch matching (Miyamoto, 2007).

Children perceive musical sounds as relative to each other in terms of sound duration. Sounds are interpreted in a temporal context when they are organized around a steady beat and demonstrate tempo regularity. This regularity is perceived most efficiently when the music is accented into continuous metrical units.

Research is now finding that a child's ability to perceive rhythm and rhythmic changes in music, and to be able to sing and drum in synchronization, and entrain to a either a fixed or slightly ambiguous beat pattern is a valid starting point to see connections between rhythmic awareness in music and how the brain processes language acquisition skills. This research seeks to explore the possibilities that there is a biological preference for a specific speed of rhythmic processing in music that is also in place in phonological processing of syllables and rhymes.

If the psychologists and neuroscientists are correct both these skills are generated in similar parts of the brain and are interdependent because both rely on auditory temporal processing skills.

2.4 Parallel Auditory processing in Music and Language

“There is so much music in the world that it is reasonable to suppose that music, like language and possibly religion, is a species-typical trait of man. Essential physiological and cognitive processes that generate musical composition and performance may even be genetically inherited, and therefore present in almost every human being” Blacking 1973 - pg 7

Such statements as this from the ethnomusicologist Blacking (1973) raised the question as to whether music, as well as language is an integral part of our evolutionary DNA. We now have neuro-scientific research that shows that they are indeed connected, whether from the results of adaptive¹⁷ evolutionary behaviour or perhaps in the sense of exaptive¹⁸ behaviour. The concept that music is an evolutionary adaptive trait has been investigated and considered to the present day (Honing 2012). Honing proposes

“that the combination of psychological, medical, physiological, genetic, phylogenetic¹⁹, hunter–gatherer, and cross-cultural evidence indicates that musicality is a cognitive adaptation” (abstract)

and is an important part of human evolution and behaviour. Even in the 19th century philosophers and scientists argued that music and language might be inter-dependent. As early as 1858 Spencer argued that music originated in the prosodic features of emotional speech whereas Darwin (1871) argued that music actually preceded language and provided the basis for “impassioned speech”.

To some music might appear to be of little use despite its constant evolution. Darwin stated that:- Neither the perception nor the production of music were “*faculties of the least use to man*” (Darwin, 1871- pg 878). “*It does not quell our hunger, nor do we live a day longer because of it*”. More recently others have echoed Darwin’s views that music is merely an

¹⁷ In behavioural ecology an adaptive behaviour is a behaviour which contributes directly or indirectly to an individual's survival or reproductive success and is thus subject to the forces of natural selection. (Starr and Taggart, 2004)

¹⁸ Exaptation refers to shifts in the function of a trait during evolution. For example, a trait can evolve because it served one particular function, but subsequently it may come to serve another. Exaptations are common in both anatomy and behaviour. Bird feathers are a classic example: initially these may have evolved for temperature regulation, but later were adapted for flight.

¹⁹ Phylogenetics is the study of evolutionary relationships among groups of species and populations.

“auditory cheesecake” (Pinker 1999) and that it is
“a pure pleasure technology, a cocktail of recreational drugs that we ingest through the ear to stimulate a mass of pleasure circuits at once”.

Although this latter viewpoint is not generally supported (Cross, 1999; Bipham, 2006a) it is not, perhaps, unknown in the general public, or indeed in Government offices that regulate the curriculum in English schools. It is, therefore, important to ensure that the opinion that music is merely a pleasurable activity that has no relevance within a school curriculum is challenged very strongly. Music, particularly with children, can be a means of beneficial play (Honing, 2011a) and can strengthen group cohesion (Cross, 2007; Kirschner and Tomosello, 2009) as well as enhancing and enabling other areas of the curriculum.

Researchers have found that the oldest parts of the brain (in evolutionary terms) are used in the detection of rhythmic activity that is needed not only for motor skills but also for the detection of rhythm in both music and language. Studies confirm that the basal ganglia²⁰ is crucial for the detection of regular beats (Grahn, 2007) and in 2011 Strait and Kraus concluded that relationships between music and speech processing are specifically driven by performance on a musical rhythm task, underscoring the importance of rhythmic regularity for both language and music. Their data indicated that common brain mechanisms underlying reading and music abilities were found in the ‘brainstem’²¹. They conclude, therefore, that there are biological underpinnings for music and reading. They go further to suggest that music should be used to promote child literacy and help remediation programmes.

During recent years, a number of other studies have shown that processing of both musical and linguistic syntax relies on overlapping cognitive resources some of which are located in overlapping brain areas

²⁰ Because the basal ganglia are found in the forebrains of all modern vertebrates, they most likely date to the common evolutionary ancestor of the vertebrates, more than 500 million years ago.

²¹ The brain stem is the oldest and smallest region in the evolving human brain. It evolved hundreds of millions of years ago and is more like the entire brain of present-day reptiles. For this reason, it is often called the ‘reptilian brain’. Various clumps of cells in the brain stem determine the brain’s general level of alertness and regulate the vegetative processes of the body such as breathing and heartbeat.

(Koelsch, 2005; Patel, 2003). Moreover, substantial evidence underlines the importance of a sophisticated processing of prosody (i.e., the “musical” features of speech) for the acquisition of language (Jusczyk, 2002; Jusczyk et al., 1992; Krumhansl & Jusczyk, 1990; Fernald, 1989). Several studies have reported a relationship between musical and prosodic abilities (Magne, Schön, & Besson, 2006; Schön, Magne, & Besson, 2004), as well as between musical and phonological abilities (Wong, Skoe, Russo, Dees, & Kraus, 2007; Anvari, Trainor, Woodside, & Levy, 2002).

An interesting study to investigate music processing in children with Specific Language Impairment (SLI) sheds light on the possibility that music and language share integrated neural resources (Jentschke et al, 2008). The SLI children have linguistic difficulties in the absence of possible explanatory factors that usually accompany language impairment. The research team hypothesized that children with SLI would also have difficulties in the processing of musical syntax. Their research with 21 SLI children aged 5 years old asked the children to differentiate between a series of chords. The last chord in the sequence was either an expected ‘tonic’²² chord, or one that was unexpected in accordance with the western musical traditions. The difficulties associated with SLI were mirrored exactly in the children’s inability to process the musical violations. The research team concluded therefore that there were shared neural resources common to both music and language which are related in the processing and storing of ordered sequences that are organized “*according to surface and regularities and underlying structures*”. This is directly in line with the view that music and speech are intimately connected in early life (Trehub, 2003), and that music paves the way to linguistic capacities (Papoušek, 1996; Fernald, 1989).

They concluded, as does Kraus and colleagues that it seems possible that music perception might implicitly train parts of the language network, and thus, be an important contribution to the treatment of children who find difficulties in decoding linguistic properties, specifically with SLI in this research.

Another working hypothesis that supports joint neural networking is

²² The ‘tonic’ chord is the chord that is built around the Key note of a scale. The vast majority of Western music will end on such a chord, especially in popular music.

proposed by Patel (2011). He reviews the current literature, with particular reference to neuro-scientific research and has then developed his ‘OPERA’ hypothesis that seeks to bring all the current theories into one framework (Figure 2.4.1).

Figure 2.4.1 The OPERA Hypothesis (Patel 2011)

The “OPERA” hypothesis proposes that such benefits are driven by adaptive plasticity in speech-processing networks, and that this plasticity occurs when five conditions are met. These are:

- (1) Overlap: there is anatomical overlap in the brain networks that process an acoustic feature used in both music and speech (e.g., waveform periodicity, amplitude envelope),
- (2) Precision: music places higher demands on these shared networks than does speech, in terms of the precision of processing,
- (3) Emotion: the musical activities that engage this network elicit strong positive emotion,
- (4) Repetition: the musical activities that engage this network are frequently repeated, and
- (5) Attention: the musical activities that engage this network are associated with focused attention.

According to the OPERA hypothesis, when these conditions are met neural plasticity drives the networks in question to function with higher precision than needed for ordinary speech communication. Yet since speech shares these networks with music, speech processing benefits.

From looking at this research one can conclude that language and music are two capacities with a mutual evolutionary history, and if they share the same neural networks then it can be argued that they are inter-dependent.

“the musilanguage stage in evolution. . .was neither linguistic nor musical but . . . embodied the shared features of modern day music and language, so that evolutionary divergence led to the formation of two distinct and specialized functions with retention of the shared features conferred onto them by the joint precursor....” Brown 2001- pg 277

2.4.1 The interaction of Music and Phonological Skills

At a very simple level it is easy to see that children's music perception and phonological awareness are related, in that both processes are based on aural perception and manipulation of auditory stimuli (Anvari, Trainor, Woodside, & Levy, 2002; Besson and Schön 2001, 2003; Patel, 2008, Strait, 2011).

The cognitive processes involved in musical activity and reading acquisition overlap in that both require abilities to perceive the order of sounds and to segment longer sound sequences into smaller units. Segmentation of the speech stream is necessary for the development of phonological awareness, an essential skill for decoding and eventual comprehension of written words both singly and in connected text. Music perception involves processing a stream of auditory stimuli marked by rhythmic time intervals and pitch/tonal variation. The ability to detect the rhythm or periodicity with which strong and weak beats recur is central to the sequential organisation of sounds in both domains. This is referred to as meter in music and as syllable stress in speech. In music the place and role of different notes in the overall sequential pattern are important, with both rhythm and pitch acting as "musical syntax" (Thaut, 2005). This is analogous to prosodic structure in language, which has been described as a "phonological grammar" (Port, 2003). Both rhythm and pitch contribute to the perception of speech prosody (Marie, 2009), and the position of syllables and the stress and pitch contour placed on different syllables contribute to the extent to which a language has easily defined prominences or accents (Arvaniti, 2009).

As we have seen rhythm in music reflects at least two aspects of temporal organisation, periodicity or metrical structure, and the patterning of musical events into similarly structured groupings, or phrase structure. In language, speech rhythm has a similar organisational role, reflecting syllable, word and clausal boundaries. The important energy fluctuations in the speech signal are rhythmic not in terms of being perfectly periodic or 'isochronous', but in terms of the motor constraints inherent in producing syllables (Chandrasekaran, 2009). For example, long and short syllables often follow

each other, as do stressed and unstressed syllables. According to Cutler's "rhythmic segmentation hypothesis" (Cutler 1996), listeners adopt the unit of metrical organisation prevalent in their language as a pre-lexical cue to word boundaries (e.g., the foot in English, the syllable in French or Spanish, the mora²³ in Japanese). Accurate metrical perception is therefore equally important in phonological learning (for example, by enabling the accurate segmentation of syllables and words from the speech stream (Echols, 1996) as it is in rhythmic perception in music (Goswami 2011; Corriveau and Goswami, 2009).

2.4.2 Auditory temporal processing

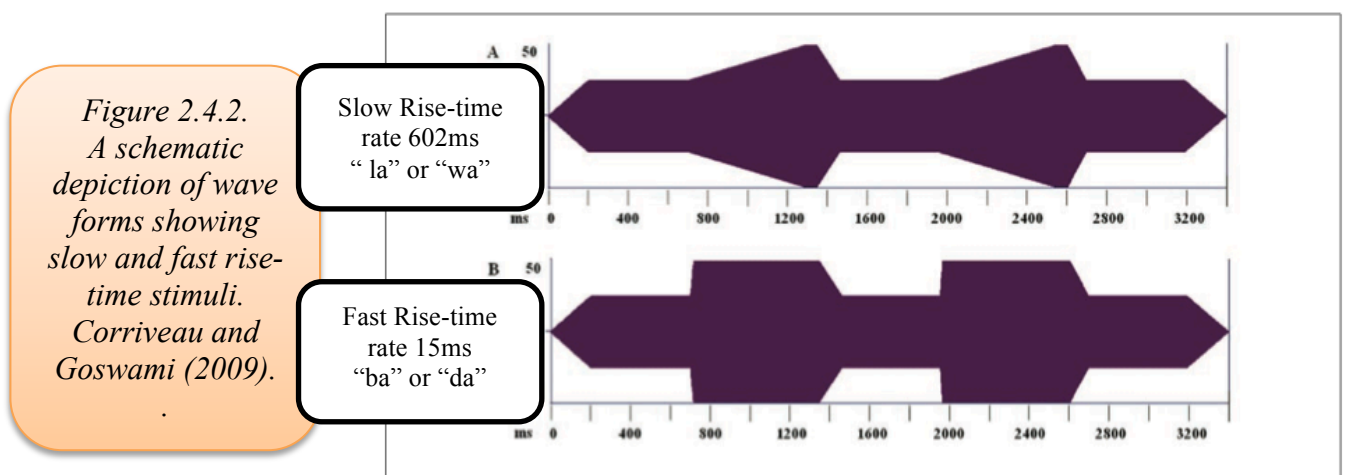
Auditory temporal processing involves the ability to perceive and integrate auditory information that enters the central nervous system sequentially over time (Tallal, 1993; Tallal, 1997). The acoustic waveform of speech is continuous, complex and characterized by rapid acoustic changes in frequency and intensity. Within the auditory patterns contained in the stimuli individual features can change within milliseconds of each other. Auditory temporal processing requires the ability to process acoustic signals over time and includes the "*ordering, integration, and resolution of auditory signals*" (Tallal & Gaab, 2006). This process is involved in human perception of auditory information, whether linguistic or non-linguistic. Consequently, auditory temporal processing influences perception of all aspects of music, speech, and general listening tasks. Children in particular must be able to process auditory information at a rapid pace in order to develop appropriate listening skills necessary for language, and to process non-linguistic sounds (Boets, Wouters, van Wieringen & Ghesquière, 2007).

2.4.3 Auditory Temporal Processing And Phonological Awareness

How the child is able to segment the speech stream rapidly into components that allow conceptualisation of the components of their phonological skills is a "*complicated and dynamic process*" (Tallal 2004). In

²³ **Mora** is a unit in phonology that determines syllable weight which in some languages, especially Japanese determines stress or timing. Clark et al (2007).

a spoken sentence or phrase there are likely to be no boundaries that segment the on-going speech stream into distinct phonemes or syllables. For a child to be able to differentiate between the syllables /ba/ and /da/, the only cue that occurs is within the initial 40-millisecond of the formation of the sound. When viewing a waveform such as that in figure 2.4.2 you can see clearly that the beginning of the sounds ‘la’ and ‘ba’ is different. In the first there is a slow rise in the waveform, and in ‘ba’ this is much more rapid. These differences are referred to as the ‘rise time’ within the acoustic signal. Before even these cues are identified the brain must segment the on-going acoustic waveform of speech into chunks of time in which acoustic patterns occur frequently and consistently. Consistencies in the speech waveform can occur in ‘chunks’ of various durations. Chunking in tens of milliseconds time might allow the fine grain analysis within the child’s brain to represent the acoustic differences between phonemes such as /b/ and /d/. Chunking over longer periods of time (hundreds of milliseconds) will result in patterns that could differentiate between syllables or word-length representations. Studies show that the auditory cortex, which is responsible for mapping these rapid changes, is shaped early in life, and the child responds to the regularity of hearing all the various cues in speech (and indeed in music) that enables differentiation of the various components of the speech stream. The child will hear the cues and then ‘compute’ the statistical probability of their occurrence to develop the meaning of the words (Saffran, 1999; 2003).²⁴



²⁴ Figure 2.4.2 shows a visual representation of the waveform ‘amplitude beats’ created by two syllables. The waveforms were created by careful manipulation of sine waves (see pg 5 Corriveau and Goswami (2009) for full description) and formed part of a ‘dinosaur’ game developed by Dorothy Bishop - Oxford University (2001) that asked children to discriminate between bell-like sounds commencing with long or short rise time.

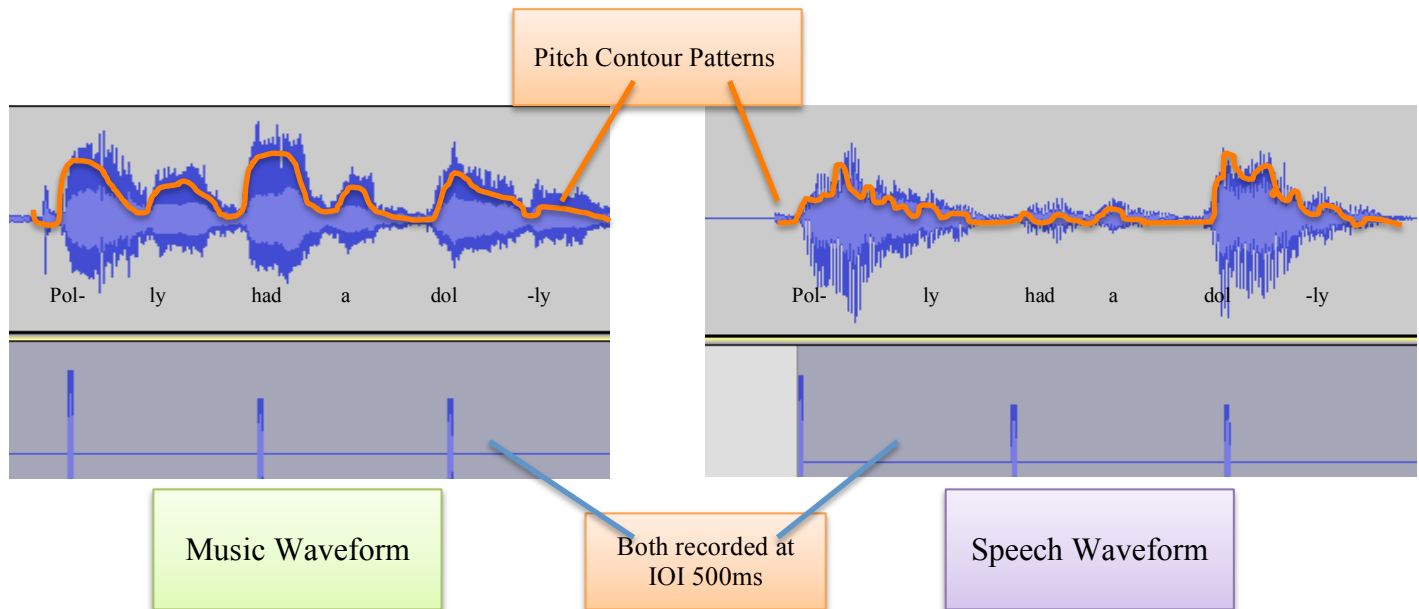
(i) Amplitude Envelope Rise-Time

In natural speech, rise-time will incorporate changes in intensity, duration, and fundamental frequency. If a syllable onsets rapidly, for example, via a plosive (“ba”, “da”), rise time will be fast and the perceived change in intensity will be relatively sharp. If a syllable onsets more slowly, for example, via a sonorant (“la”, “wa”), rise-time will be extended in duration and the perceived change in intensity will be more gentle (Figure 2.4.2).

For example, when chanting to a rhythm, participants use rise-time in order to produce syllables at isochronous intervals (Scott, 1998). When you try to do this you have to match the beat with the ‘perceptual centre’ of the syllable. – the ‘p’ centre. This need not be at the onset of the syllable, but might be slightly delayed. When a child chants ‘Twinkle Twinkle little star’ to a deliberate pulse, they need to begin saying a syllable that starts with a longer onset, such as “twinkle / star / sky”, earlier than a syllable that has a shorter onset, such as “diamond”. Longer onsets before the vowel (e.g., “star”) move the P-centre temporally to the left on a spectrographic representation of a waveform such as that shown in figure 2.4.3. In some other nursery rhymes the ‘p’ centre would move to the right if the word has a long ‘coda’ (e.g., “sick, sick, sick” – in Miss Polly has a Dolly) (Port, 2003). One has to take these into consideration when analysing the accuracy of children’s singing by looking at visual spectrographic representations of their performances such as those shown in Figure 2.4.3.

Figure 2.4.3 shows that both the spectrographic representations of the phrase ‘Polly had a dolly’ have a defined accented pattern, but in the sung representation the strong/weak beats are more clearly defined. One can also see the accurate timing of ‘Pol’ and ‘Dol’ against the pulse beat where the ‘p’ centres are close to the onset of the syllable.

Figure 2.4.3 Representations of waveforms in a Nursery rhyme phrase in music and speech. Both examples were recorded using 'Audacity' software by the researcher with an IOI pulse rate of 500ms - John P. Verney



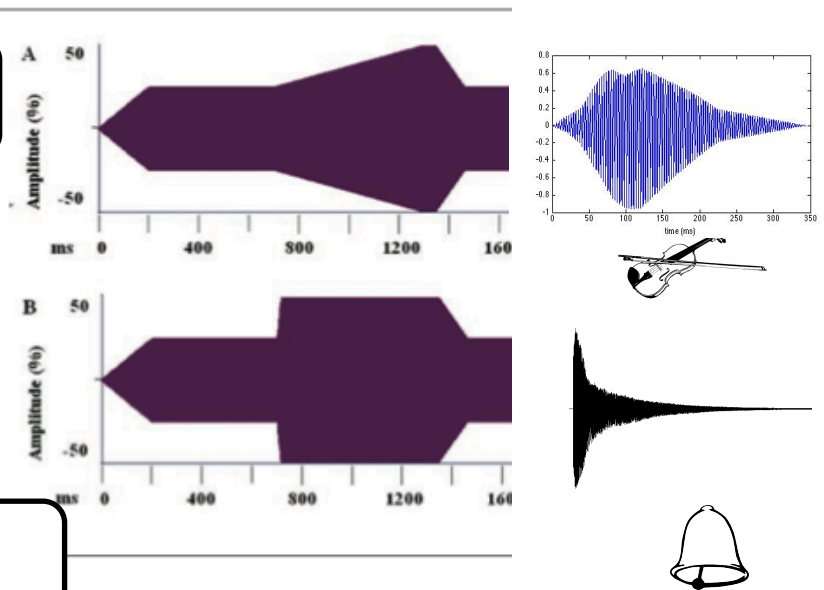
The rise-time events drive the allocation of attention to speech processing, possibly via the alignment of internal and external oscillatory rhythms (Kotz and Schwartz. 2010). Kotz and Schwartz noted that their theoretical framework had implications for both language development and for the perception of music, since both need motor timing and motor sequencing capacities. They also considered, like Honing, that temporal processing was a phylogenetic development that evolved from “*primitive subcortical structures*” and evolved to such an extent that it could alter behaviour and impact on speech production.

Within a musical context where meter is established through strongly accented notes, it will be much easier to discriminate the accents if they are very percussive, in other words have a short rise time such as a beater hitting a bell, than if they are longer – a bow starting a note on a violin. Figure 2.4.2 could easily be adapted to show this (Figure 2.4.4.)

Slow Rise-time
Violin played using legato bowing.

Figure 2.4.4.
A schematic depiction
of wave forms showing
slow and fast rise-time
using musical
instruments as stimuli
instrument – adapted
from Corriveau and
Goswami (2009) by
John P. Verney

Fast Rise-time
Glockenspiel



Goswami (2012) is in agreement with Kotz and Schwartz maintaining that rise time is the critical auditory cue for rhythmic timing in language and music, across languages from different rhythm classes, in both perception and production (Vos & Rasch, 1981; Morton et al., 1976; Gordon, 1987; Hoequist, 1983; Scott, 1998) and that individual differences in the severity of the rise time impairment are strongly predictive of the degree of phonological impairment, suggesting that accurate rise time perception is particularly important for developing the high-quality phonological representations of language required for the acquisition of literacy.

(ii) Temporal Sampling Theory

A theory that seeks to shed light on these difficulties with phonological representations is the ‘temporal sampling theory’ (Goswami 2011). This proposes that the difficulty that we see in children across the IQ spectrum who are unable to entrain to a rhythmic beat or notice small fluctuations of rhythm (Huss & Verney 2011) is caused by a neural deficit in rhythmic entrainment. The deficits in rhythmic entrainment are mirrored in deficits in the ability of the child to notice changes in ‘rise- time’ at the onset of syllables. This means that they do not process speech rhythm accurately and

therefore they find it difficult to develop good phonological awareness skills (Wood & Terrell, 1998; Goswami, 2011, Goswami et al., 2010; Huss et al., 2011, Leong et al., 2011).

Goswami (2011) proposed that the cause of this deficit is brain-based, and those who cannot identify these subtle changes in rhythm find it difficult to extract different modulation frequencies in the speech envelope, particularly in the low frequency modulations in the Delta (0.5 – 4 Hz) and possibly also in the Theta (4 – 8 Hz) frequency bands.²⁵ These frequency bands carry information about syllables and prosody (Hickok & Poeppel, 2007; Ghitza & Greenberg, 2009) and have been identified in brain-based studies using EEG²⁶ methodology.

Developmental inefficiencies in basic auditory processing might therefore be expected to affect both language development and the development of musical abilities.

Both rhythm and pitch contribute to the perception of speech prosody (Marie et al., 2011), and the position of syllables and the stress and pitch contour placed on different syllables contribute to the extent to which a language has easily defined prominences or accents (Arvaniti, 2009). In the prosodic structure of language (Cummins & Port, 1998; Port, 2003; Goswami, 2011; Goswami, 2010) one can see that the position of syllables and the stress placed on different syllables in the sequence of acoustic patterning is a kind of prosodic or phonological “grammar” (Port, 2003) that matches with the musical syntax defined by the accents in the musical phrase.

Research confirms that adults and children who have had intensive music lessons are more likely to be sensitive to speech sounds than non-musicians. In experiments by Gottfried et al., (2004), Delogu et al., (2006, 2010) and Lee and Hung, (2008) Elmer et al., (2011) it was found that

²⁵ Delta is the frequency range up to 4 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep. It is also seen normally in babies. Theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children.

²⁶ Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain.

musicians detected tone and segmental variations better than non-musicians. Magne et al., (2007) and Marie et al., (2011) examined the influence of musical expertise on vowel duration and metric processing in natural speech (Magne et al., 2007; Marie et al., 2011). They used a specific time-stretching algorithm (Pallone et al., 1999) to create an unexpected lengthening of the penultimate syllable that disrupted the metric structure of words without modifying timbre or frequency. Participants performed two tasks in separate blocks of trials. In the metric task, they focused attention on the metric structure of final words to decide whether they were correctly pronounced or not. In the semantic task, they focused attention on the semantics of the sentence to decide whether the final word was expected within the context or not. In both tasks, musicians outperformed non-musicians. These results seem to show that, compared to non-musicians, musicians are more sensitive to the metric structure of words (Marie et al., 2011).

These results imply that, with years of musical practice, musicians have developed an increased sensitivity to acoustic parameters that are important for music, such as frequency and duration, and these might also help in their sensitivity to the metrical structure of language (Strait 2011, Mussacchia, 2007). These studies are relevant and their results are generally in line with the behavioural studies that showed there was a positive influence of musical skills on phonological processing at a young age (Anvari, 2002, Overy 2003, Moritz 2007; Forgeard, 2008), but we need to look more closely at studies and theories that connect more directly to the young developing brain and are not dependent on the advantages that might occur if children are given increased musical opportunities that are not available in a general educational setting.

One of the most obvious links is that we have a capacity to link music and language through song – to highlight the natural rise and fall of our language – the prosody – by linking it to specific tones. This is an activity in which children and adults engage without any specific training.

(iii) Music and Language are linked through ‘song’

Songs are created through the process of text-setting, in which the prosodic features of speech are combined with a musical melody, uniting their separate metrical structures and forming one rhythmic pattern (Halle and Lerdahl, 1993). In the process of text-setting, song composers often align linguistically strong syllables with musically strong beats (Kimball, 1996). Since English is generally regarded as a stress-timed language we find that this is particularly true in a corpus of English songs (Palmer and Kelly, 1992). In other words, stressed syllables, or syllables that one would expect to be stressed in speech (“strong” syllables), are more likely than unstressed (“weak”) syllables to occur on hierarchically prominent musical beats.

This alignment of strong syllables with musically strong beats is thought to aid memorization and communication (Palmer and Kelly, 1992; Gingold and Abravanel (1987)) – thus giving a reason why young children learn some songs such as ‘Mickey Mouse’s House’ so easily (Figure 2.4.5).

Figure 2.4.5 Mickey Mouse’s house- strong and weak accents

> =Accents

Mickey mouse's house

Syncopated passage where the accent is deliberately moved from its normal position

John P. Verney

Mick - ey the mouse; Mick - ey the mouse; he plays mus - ic all round the house.

Mick - ey the mouse; Mick - ey the mouse plays the mus - ic in - side his house.

S w w S S w w S w w S w S

“Song is an ecological model for studying the complex relationship between music and speech” (Gordon et al, 2011), and has been examined in recent studies with cognitive neuroscience methods that have found interactions between various aspects of the linguistic and musical dimensions found in songs (Lidji et al., 2009; Gordon et al., 2010; Schön et al., 2010). The Gordon study (2011) was designed to explore the idea that temporal alignment helps listeners to better understand song lyrics by directing listeners’ attention to instances where strong syllables occur on strong beats. EEG recordings were taken while participants listened to the sung sentences (primes) and performed a lexical decision task on subsequent words and pseudowords (targets, presented visually). Overall, these findings suggest that alignment of linguistic stress and musical meter in song enhances musical beat tracking and comprehension of lyrics by synchronizing neural activity with strong syllables. Moreover, the observations reported here coincide with a growing number of studies reporting interactions between the linguistic and musical dimensions of song, which are likely to stem from shared neural resources for processing music and speech. Experiments with adults also point to the efficacy of emphasizing both the linguistic (Wallace and Rubin, 1988; Wallace, 1994) and musical (Purnell-Webb and Speelman, 2008) rhythm during song learning.

The stress and accented patterns are part of the prosodic structures in language. Within the context of a phrase rather than a syllable there are also repeated groupings; for example questions in English will generally end with a rising contour. Prosody is a term used in linguistic theory that covers all aspects of grouping, rhythm and prominence in spoken language, from sub-parts of the syllable up through the organisation of words in the phrase (Lehiste, 1970; Pierrehumbert, 2003). Many linguists propose that the units of prosodic organisation are arranged into a hierarchical structure, so that, for instance, syllables form feet (strong and weak syllables), feet form words, and words form intonational phrases. Sensitivity to periodicity may provide a basic temporal “skeleton” enabling neural entrainment and the encoding of the syllable structure of speech (or the basic beat structure of music). The development of processing mechanisms able to encode deviations from isochrony (Honing 2011, Large, 2002) can then be scaffolded onto this basic

periodic temporal framework. This scaffolding can be done through the linking of music to language in a song.

A slight modification of the previous studies, suggesting shared neural networks, is postulated by Peretz and Coltheart (2003). She suggests that music and language are initially independent of each other and come together when needed, specifically when the brain needs to join speech and music together in song. She believes that the examination of individuals who were neurologically intact prior to cerebral insult can reveal the degree to which a given site of brain activity is responsible for specific cognitive functions (Peretz, 1996; Peretz, & Zatorre, 2005; Peretz, et al 2004). Peretz's argument begins by asserting the independence of music and language modules (Peretz & Coltheart, 2003). Peretz's model of music function proposes a hierarchical, modular organisation with different pathways for pitch, temporal and musically-related phonological information through to higher functions that govern music recognition and interpretation.

2.4.4 The Peretz and Coltheart Framework (2003)

The framework is a highly adaptable design and can be used to link music and language processing in either domain and has relevance for investigation into dual and integrated processing with both children and adults. Welch (2005) adapted the design to explain processing in singing and Goswami (2009; 2012) has modified it in her research that links rhythmic timing in music and language with specific reference to children with specific language impairments and dyslexia... (see figures 2.4.6. and 2.4.7.)

Figure 2.4.6
An adapted modular model of music processing
(Welch, 2005)
of Peretz and Coltheart (2003)

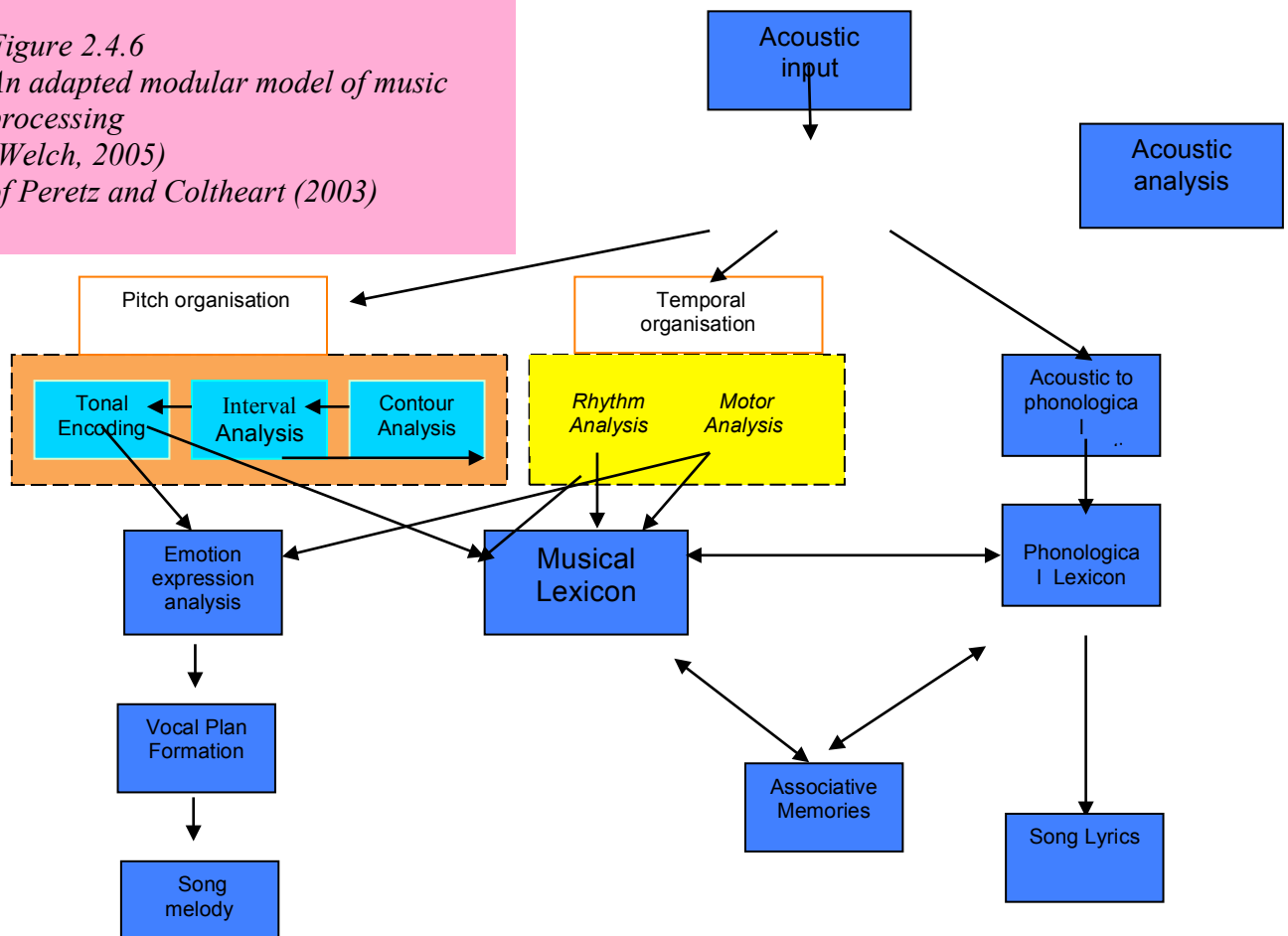
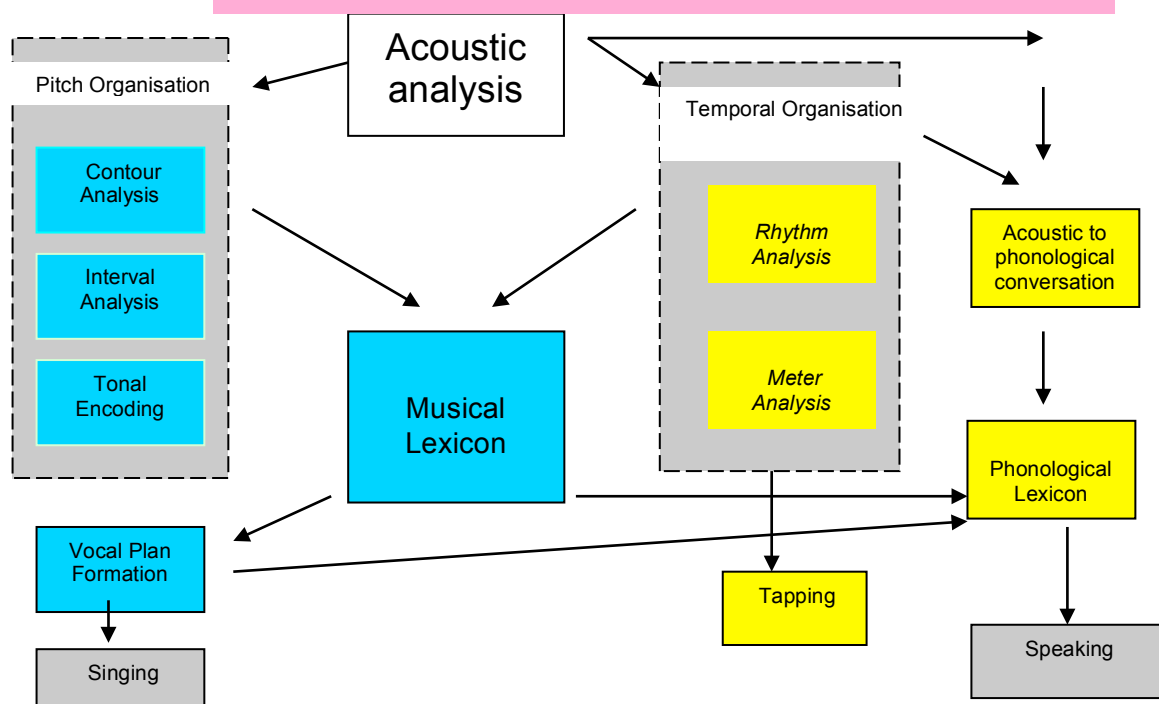


Figure 2.4.7
An adapted modular model of music processing (Goswami 2009)
of Peretz and Coltheart (2003)



In the Peretz and Coltheart (2003) model, acoustic processing follows two “streams”, a pitch organisation stream (impaired in amusia) and a temporal organisation stream (preserved in amusia). The temporal organisation stream includes rhythm analysis, meter analysis and tapping skills. Investigations with brain damaged patients, who could in certain cases remember lyrics to songs but not melodies and vice versa, helped Peretz and Coltheart (2003) to formulate their developmental hypothesis that showed that music processing might have a discreet modular organisation but had inbuilt flexibility to change and be modified when needed. Their model of music processing illustrates that at times, particularly in singing, the discrete language and music boxes need to combine and interact. If you want to sing a song then information about a melody that is stored in the ‘music lexicon’ will need to be paired with the lyrics stored in the phonological lexicon and then ‘tightly integrated’ to produce a vocal output.

In a small-scale study, with only five adult participants (Anderson et al 2012), a professional singing teacher used a broad-brush intervention approach to a group of participants diagnosed with congenital amusia. The compensatory elements were designed to enhance vocal efficiency and health, singing technique, musical understanding, pitch perception, and production. Improvements were observed in most individuals in perception, indexed via the Montreal Battery for the Evaluation of Amusia scale subtest and in the vocal performance of familiar songs. The researchers concluded that because these abilities were improved it was possible that congenital amusia may not be entirely immune to environmental modification, and that some of the musical difficulties arose because of a lack of musical stimulation in early childhood.

Peretz and Coltheart tested their framework using tasks very similar to those that test a child’s interaction with musical structure such as contour, interval, scale, rhythm, metre and memory. For example, Dalla Bella and Peretz (2003) compared the reactions of a group of 8 adults with “congenital amusia” and a control group of 9 unimpaired adults who were asked to tap in time with various musical scores and simple bursts of sound (the synchronisation of tapping was measured by the millisecond). The amusic participants scored considerably less well than the control group in the

musical task, but there were no significant differences when reacting to the sound bursts. Peretz and Coltheart concluded that the processing of the auditory stimuli was different in music to general sound, and so music perception had to be regarded as a distinct modular skill. Peretz and Coltheart's modular framework suggests that mechanisms supporting pitch organisation versus rhythm organisation may contribute to music versus language respectively. The 'temporal organisation stream' is intimately linked to the development of the phonological lexicon (Goswami 2012) because in music and language, the key perceptual mechanisms are auditory.

Prior research has suggested that dyslexic' speech sound segmentation problems are due to temporal difficulties in processing rapidly presented auditory stimuli caused by a non-speech rapid temporal processing deficit (Tallal, 1993). In recent years, other research has provided more evidence of dyslexics' temporal processing deficits through identifying problems with auditory temporal sensitivity (Wolff, 2002, Thomson, 2008), rapid speech perception (Wood & Terrell, 1998), and detection of complex timing patterns (Kujala et al., 2000). Since both phonological and music processing involve timing, and involve common areas of the brain associated with timing, such as the cerebellum (Besson & Schön, 2003; Nicholson, Fawcett, & Dean, 1995), it has been hypothesized that music activities which involve sensitivity to timing may be able to bolster reading.

2.4.5 Implications for the research paradigm

In this study it is proposed that basic fundamental auditory processes are required for the child to extract periodic temporal structure when perceiving both music and language. These basic auditory processes may affect both the perception of metrical structure in music and the development of the language processing skills measured by PA tasks, which in turn would be expected to affect literacy acquisition. These processes are not dependent on years of intensive study. None of the children in this research have had formal music lessons, but the hypothesis in the study is that even a short period of increased exposure to rhythmic tasks delivered via a musical medium could increase the likelihood of improved phonological skills without the advantages given by learning a musical instrument. However,

nearly all children interact with both music and language through song or rhythmic chants. Cummins (2010) argues for the core role of motor processes in perceiving and producing rhythmic speech events.

“When speech is turned into chant, rap, verse or song, we find a marriage of rhythm in the musical and phonetic senses. When children in the playground turn a single exclamation or taunt into a repeated mantra, its rhythmic potential is unleashed” Cummins 2010 pg 6.

Cummins notes that although speech appears highly specialised and detached from general bodily rhythms, in fact it shares the same rhythmic constraints of any cyclic movement of the limbs (walking, dancing, juggling...). The temporal relationships between the sequencing of syllables, their organisation into larger linguistic units (foot, phrase) and their positions (relative timing) with respect to each other, cannot vary freely because of the constraints imposed by physiology. Cummins argues that speech is a whole-body activity, and in some key respects is similar to musical performance. His view is that rhythm in speech and rhythm in music are related via embodiment and entrainment. Music clearly involves embodiment, we usually cannot help tapping along or internally feeling the rhythm, but embodiment in language has been far less studied. Cummins (2010) makes a very plausible case that there should be important links between rhythmic embodiment and linguistic behaviour.

With this in mind the research paradigm will compare the results of a three-group intervention where the effects of rhythmic training are compared with a control group. One group will receive phonological training based on syllable and rhyme awareness through a music programme that includes tapping along to both instrumental music and songs, and the second group will receive an intervention based purely on chanting the rhythms, with no ‘music’ – eg no musical accompaniment backing tracks or singing – in other words without any concentration on pitch accuracy.

2.5 A review of studies that have shown that music impacts on literacy development

In this final section of the literature review I look at training studies that have investigated causal links between the teaching of musical skills and an improvement in both phonological awareness and reading. First I look at three studies that have come from investigations into the causes of dyslexia, where researchers have found differences between the dyslexic child and the normally developing child in connection to rhythmic entrainment.

Secondly I look at more broadly based classroom based strategies that seem to show that an increased emphasis and exposure to music will help children access the literacy curriculum.

(i) **Studies exploring music and the causes of developmental dyslexia**

According to Goswami and colleagues, the Peretz and Coltheart (2003) model provides a theoretical framework for considering developmental dyslexia, because research has consistently shown that children with developmental dyslexia are impaired at tapping to a rhythm, and in perceiving tempo, and yet have few problems in fluent speech (e.g., Corriveau and Goswami, 2009; Thomson and Goswami, 2008 Wolff, 2002; Wolff et al., 1990). Following a series of studies of children's auditory perception of tasks (e.g., Corriveau & Goswami, 2009; Thomson & Goswami, 2008), Goswami proposed that while amusic brains can be described as being:-

“out of tune but in time” (Hyde & Peretz, 2004), the brains of children with developmental dyslexia or specific language impairment (SLI) may be brains that are “in tune but out of time”. Corriveau 2009 - pg 129

In a study of 10 year-old children with dyslexia, children were asked to entrain to a metronome beating at various rates (400 ms, 2.5 Hz; 500 ms, 2 Hz; and 666 ms, 1.5 Hz). Children who were particularly inconsistent in tapping to a particular rate showed the poorest literacy and phonological development. These data could not be explained by general motor dexterity, which contributed no unique variance to any of the literacy or phonological

processing measures, or by auditory rhythmic difficulties (rise-time discrimination) (Thomson, 2008). Recent research (see Huss & Verney et al. 2011, Goswami, Huss et al, 2012) suggests that of the above rates used in the Thomson tests one might be significantly more useful than the others.

In the Huss and Verney study in addition to the battery of behavioural tasks I helped devise an additional music task to explore relations between musical metrical perception and auditory perception of amplitude envelope structure, phonological awareness (PA) and reading in a sample of 64 typically-developing children and children with developmental dyslexia.

The test consisted of a series of varying metrical discrimination tasks where the children had to say whether two rhythmic excerpts were the same or different. The musical excerpts were simply a two bar rhythm pitched to G using a simulated chime bar sound played at a pulse rate of 500ms. The differences between the two pieces were simply that one accented beat was made either 100 or 166 milliseconds longer on the second hearing (Figure 2.5.1).

Figure 2.5.1. Musical example from the Huss et al study. 2011. 'Music, rhythm, rise-time perception and developmental dyslexia: Perception of musical meter predicts reading and phonology' from Table 1 pg 679.



The results showed that musical metrical sensitivity predicts PA and reading development, accounting for over 60% of variance in concurrent word reading along with age and I.Q. The task showed stronger associations with reading (42% of unique variance) than traditional phonological awareness measures (a rhyme awareness measure predicted 33% of variance). When the same group of dyslexic children performed the same task a year

later their performance was actually poorer than before, suggesting that their inability to perform the task showed a more robust perceptual deficit (Goswami and Huss, 2012). The children with dyslexia performed even the simplest metrical task, based on a duple metrical structure, significantly more poorly. The conclusion from this research adds weight to the findings of the Thomson study in 2008. Both studies indicate that accurate perception of metrical structure may be critical for phonological development and consequently for the development of literacy. In the Huss and Verney study I concluded that the 500ms rate could be significant. The conclusion that the 500ms rate is of biological significance can be found in other research protocols (Moelants 2002, Taub 2007). MacDougall and Moore (2005) studied the spontaneous tempo of walking in humans and found that preferred gait was 2 Hz irrespective of gender, height, weight, age or body mass index. They suggested that 2 Hz (500 ms) could represent a spontaneous tempo or “resonant frequency” of human movement. This observation is consistent with a number of developmental and linguistic studies of spontaneous tempi such as that by Arvaniti (2009), who noted that across languages stressed syllables are produced on average every 500 ms suggestive of a biological constraint linked to the articulators, and when adults read aloud from text, they show a bias for inter-stress intervals which are multiples of a 500 ms unit (Fant and Kruckenberg, 1996).

Overy (2003) performed experimental studies of the use of music as a remediation technique for children with reading disability. She reported on the results of two experimental studies where music activity was used specifically to bolster reading in dyslexic and at-risk children. In the first study, 28 children (mean age 6.7 years) were classified as at strong risk, mild risk, or no risk of dyslexia and were given one-hour singing-based music training each week, usually in three 20-minute sessions, by their regular classroom teacher over the academic year. There was no control group in this study; scores were just compared with national norms. In the second study a trained music teacher gave nine boys with dyslexia in two schools music lessons each week. The content of the thrice-weekly 20-minute lessons emphasized musical rhythm exercises. The nine boys formed their own

control group by being monitored for a 15- week period prior to the 15-week intervention period. In the first study, children at strong and mild risk of dyslexia showed significant improvement in spelling skills, and all groups improved in phonological segmentation skills. In the second study, the boys with dyslexia showed significant improvement in phonological processing and spelling skills. Neither study showed improvement in overall reading skills, but rather in the reading subskills of phonological awareness and spelling.

(ii) Studies exploring music to promote literacy development

Specific musical training can improve understanding of timing, pitch grouping and harmonic sequences (Jentschke, Koelsch et al 2005), and this enhanced information could have benefits for language acquisition (Schellenberg 2005). Jentschke tracked the responses to sentence comprehension and music perception when children's expectations were violated by syntactical violations in sentences and harmonic violations in music. The research was with musically-trained or non-trained 11- year-old and with 5 year-old children, some of whom had language impairment.

Jentschke commented:-

“We observed indicators for an intricate relationship of syntax processing in language and music --- the data suggests that children can profit from musical training because of a more efficient processing of musical structure and because of its impact on the processing of linguistic syntax. This relationship might be especially important as well in therapy for language impaired children.” pg 240

In a significant study Anvari et al., (2002) reported that music skills were found to correlate significantly with both phonological awareness and reading development in four-year-old children. In their study of 100 English speaking four- and five-year-old children, they tested both linguistic and musical skills. They devised a series of music tests for assessing discrimination of pitch, rhythm, and harmony, and rhythmic production and also a phonemic awareness test to measure rhyme generation, oddity discrimination, and phoneme blending. In the music tests the participants had

to say whether rhythms, melodies or chord sequences were the same or different. They administered the Rosner Test of Auditory Analysis Skills (Rosner, 1979) to assess the ability to segment sounds in speech. The researchers tested the children's ability in number, digit span (auditory memory), and vocabulary, exploring the role of phonological awareness, auditory memory, vocabulary, and number skill in the relationship between music and reading. The researchers took age into account by exploring the differences between four- and five-year-old children. Their results showed that the four-year-old children's musical skills, pitch and rhythm together, were significantly positively related to phonological and reading measures. By contrast, pitch processing, but not rhythm, was significantly positively correlated with phonological awareness and reading in five-year-old children. Anvari et al., found that the results varied by age in terms of relationships with rhythm perception and production. That is, rhythm perception and production showed a significantly positive relationship with phonological awareness in four-year-olds, but not in five-year-olds. The researchers hypothesized that young children's rhythmic skills developed before their acquisition of knowledge of melodic concepts. *(This is an important distinction for this study since the age of the children tested in this study were generally below the age of 5)*

According to the authors, the relationship between music perception and phonological awareness points to common auditory mechanisms underlying the development of both. For example, both phonological awareness and music perception involve segmentation of an auditory signal into smaller units. Children also need to recognize these categories or individual auditory units in spite of changes in tempo, pitch, speaker or performer, and varying acoustic conditions. As an extension of their conclusions, the authors theorised that some auditory processing abilities might overlap between music perception, phonological awareness, and reading, namely, temporal sequencing, frequency resolution, and temporal resolution.

Prior to this study only one other published study had compared reading readiness and musical ability in pre-readers and that was with only 16 four and five year-old children (Lamb and Gregory (1993). Lamb and

Gregory presented the children with pitch and timbre discrimination tasks, phonemic awareness, and a simple reading test. They concluded that phonemic awareness correlated with simple reading ability and that pitch discrimination was significantly correlated with phonemic awareness.

Walton (2007) tested a group of 97 children in kindergarten (aged 5 years) and found that exposure to songs that deliberately focused on phonological skills such as rhyming and syllables did help the trained children make more progress in their learning of key pre-reading skills (i.e., phonological awareness, letter-sound knowledge) and word reading, than those in a control group. He did not however differentiate between impact on children with lower ability and those with normal developing phonological skills.

David, Wade-Woolley, Kirby, and Smithrim (2007) performed a longitudinal study of the relationship between rhythm production (i.e., beat competency), phonological awareness, and reading development. In order to assess rhythm production ability at the beginning of the study, the researchers used the Rhythmic Competency Analysis Test (Weikart, 1989). The six-year-old participants (N=53) tapped the beat with their hands and walked to the beat (Weikart, 1989). During the initial testing phase, the researchers also tested the children's phonological awareness using a variety of measures, including Sound Oddity (Bradley & Bryant, 1983), Blending Phonemes, Blending Onset and Rime, Phoneme Elision, and Sound Isolation (Wagner et al., 1993).

Results showed that children's scores on the phonological awareness subtests correlated with one another. Therefore, the researchers combined the sub-test scores into a phonological awareness composite. Beat production showed a significantly positive correlation with phonological awareness at age six. Results also showed that after controlling for phonological awareness, beat competency was a significant predictor of reading at age ten. David et al. (2007) conclude that the overlap between phonological awareness and music perception may possibly be due to skills in blending and segmenting sounds and in temporal sequencing.

In another study examining the relationship between phonological awareness and rhythm perception and production skills in young children,

Moritz (2007) tested kindergarten-age children (N=30) at the beginning and end of the school year. The researcher studied various components of phonological awareness, including segmentation of syllables, rhyming discrimination, and isolation of medial phonemes, using the Phonological Awareness Test (Robertson & Salter, 1997). In order to assess tempo production, rhythm pattern production, and rhythm pattern discrimination, Moritz used an adapted version of the Music Aptitude Test (Overy, Nicolson, Fawcett, & Clarke, 2003). The researchers also measured non-verbal intelligence using the Kaufman Brief Intelligence Test (K-BIT, Kaufman & Kaufman, 1990). An experimental group received daily Kodály music lessons for the entire school year, while the control group received weekly music lessons that were not based on Kodály. Data showed a significantly positive relationship between rhythm production abilities and segmentation of syllables, as well as the phonological awareness composite, for all children at the beginning of the school year. At the end of the school year, results showed differences between children who received weekly or daily music lessons in regard to the relationships between phonological awareness and rhythmic skills. Children who received only weekly music lessons showed a statistically significant positive correlation between rhyming discrimination and rhythm discrimination; all other correlations were non-significant. By contrast, children who received daily Kodály lessons showed significantly positive correlations between rhythm pattern production and two phonological awareness skills: rhyming discrimination and isolation of medial phonemes. Based on results from children receiving daily Kodály lessons, the author suggests that activities involving production of rhythm patterns or songs with rhyming lyrics could be used to bolster phonological awareness skills (Moritz, 2007).

Findings from both David et al. (2007) and Moritz (2007) suggest that rhythm perception and production are significantly related to certain aspects of phonological awareness. Specifically, rhythm production (i.e., entrainment to a beat) showed a consistently positive relationship to phonological awareness. However, results regarding the relationship between rhythm pattern perception and phonological awareness were inconclusive and according to the researchers warranted further investigation.

Forgeard et al. (2008) also studied music and phonological processing in 44, six-year-old children. Thirty-two of the children had received instrumental music lessons, while twelve had not received lessons. The researchers used the Primary Measures of Music Audiation (PMMA; Gordon, 1986) as well as a researcher-designed pitch and rhythm discrimination task to measure music perception, and also used the Auditory Analysis Test (Rosner & Simon, 1971) to evaluate phonological awareness. Results showed that children's phonemic awareness was significantly and positively correlated with both pitch and rhythm discrimination. Data showed non-significantly stronger relationships in children who had received music lessons as opposed to the control group.

Boldoc (2009) researched the effect of two music training programmes on the development of both musical understanding and phonological awareness amongst 104 Franco-Canadian kindergarten children. The experimental group (N, 51) participated in an adapted version of the Standley and Hughes music training programme, devised for children in special schools, while the control group (N, 53) took part in the Ministère de l'Éducation du Québec music programme. Both programmes involved playing tuned percussion instruments, singing and musical improvisation. The control group activities were more focused on listening and interpretation of musical examples. The analysis of data shows that both music programmes contributed similarly to the development of tonal and rhythmic perceptive skills. However, the experimental music training programme proved to be more effective when it came to developing phonological awareness skills. The researchers observed that participants who were exposed to the experimental music training programme experienced an improvement in their performance, particularly in the syllable identification tasks and the rhyme and phoneme identification tasks, by the end of the programme compared to the control group. The material used throughout the programme, especially the children's songs helped the children recognise different phonological units and helped them to manipulate them purposefully and at their own pace. The researchers concluded that their results showed that there are important links between auditory perceptions, phonological memory, and metacognitive

skills and these links are crucial in the development of musical and linguistic abilities in pre-school age children.

An interesting related study, and one that has a similar structure to the second study investigated in this PhD, by Degé and Schwarzer (2011) investigated the effect of a music programme on phonological awareness in 5 to 6 year-old preschoolers. Their hypothesis was that if language and music share basic processing mechanisms, the effect of both programmes on enhancing phonological awareness should be similar. In particular, the effects of a music programme and a phonological skills programme on phonological awareness were compared. Forty-one preschoolers (22 boys) were randomly assigned to a phonological skills programme, a music programme, and a control group that received sports training (from which no effect was expected). Preschoolers were trained for 10 min on a daily basis over a period of 20 weeks. The sessions contained joint singing, joint drumming, rhythmic exercises, meter execution, training of rudimentary notation skills, dancing, and playful familiarization with intervals. In a pretest, no differences were found between the three groups in regard to age, gender, intelligence, socioeconomic status, and phonological awareness. Children in the phonological skills group and the music group showed significant increases in phonological awareness from pre- to post-test. The children in the sports group did not show a significant increase from pre- to post-test. The researchers concluded that the positive effects of the music programme basically drove enhancement of phonological awareness, in particular phonological awareness of large phonological units (e.g., rhyming, segmenting, and blending). This enhancement is comparable to the effects of a phonological skills programme on phonological awareness. Their data suggests that phonological awareness can be trained with a phonological skills program as well as a music programme and they conclude that it seems highly likely that language and music share processing mechanisms, explicitly sound category learning mechanisms. All of these classroom-based studies lend support to the idea that basic skills underpin learning across the curriculum. That is, when memory skills are developed within one domain, such as music, children naturally may apply the skills to task performance in other domains if task demands are similar and skills learned in one domain

are useful for performance of tasks in another. Music teachers can assist children to improve their memory for sound by teaching patterns within music contexts through meaningful exercises, games, and songs.

These studies using music to teach reading skills are very diverse in terms of their interventions. Some focus on pitch, others rhythm production and some a combination of both. The type of music stimuli used to target specific literacy target outcomes therefore is very varied. Consequently, generalization becomes difficult, in terms of the specific techniques that were used and precisely how the findings could be attributed to the music interventions. Furthermore, the age of the samples in the various studies included children from 5 – 11 years old. These methodological differences further contribute to the difficulty in generalizing results across studies. However despite the inconsistencies there is sufficient evidence to further pursue the links. Increasing evidence now supports the ‘temporal sampling theory’ of Goswami that provides evidence-based reasons for a shared deficit in rhythmic processing in both rhythmic perception in music and language.

A small scale intervention unpublished study (Bhide et al, 2012) suggested that a theoretically-driven musical intervention based on rhythm and on linking metrical structure in music and language could have benefits for the development of literacy and phonological awareness. This study with 19 children aged 6 – 7, all of whom were struggling readers compared the impact of a computer assisted reading programme with a musical rhythm programme that asked the children to tap along to 5 different speeds (60 bpm, 80 bpm, 100 bpm, 120 bpm and 140 bpm). Significantly the children who showed the poorest rhythmic entrainment at the beginning of the intervention made the greatest improvements. There were also correlations with improvement in rhythmic performance and reading. The effects found suggest that giving children rhythmic training, and linking non-linguistic rhythms to rhythms in language, has a positive effect on literacy acquisition and on phonological skills.

Chapter 3 Methods and Procedures

Aims, hypotheses and research questions in the study

All the different theoretical perspectives linking language and music under review (Goswami, 2011; Kotz and Schwartz, 2010; Patel, 2011, and Cummins, 2010) place entrainment at the core of rhythmic behaviour. The common perceptual capacities for music perception and phonological awareness point to parallel auditory processing mechanisms (Patel, 2008). Music and speech have common acoustic parameters, consisting of spectral and temporal qualities that are processed by overlapping neural mechanisms (Patel & Peretz, 1997). One of the reasons for these links or ‘overlap’ (from Patel’s **Opera** framework, 2008) is that regardless of whether an auditory stimulus is a speech or musical signal, the auditory system perceives rapidly-occurring temporal information or spectral information from either signal in similar ways. Over time, the young child’s skills in perception of speech and music become increasingly refined, showing dramatic improvement during the first five years of life e.g. McPherson (2006).

From this statement and others discussed in the literature review we can devise a series of hypotheses which need exploration and which determine the research questions and methods employed in the study.

1. Developmentally different (yet mutually consistent) theoretical frameworks predict that children who show more accurate rhythmic entrainment might also show superior musical and linguistic performance.
2. There is evidence to support a relationship between rhythmic entrainment, language and music.
3. In the ‘temporal sampling theory’ Goswami proposes that it should be possible to see a relationship between rhythmic entrainment and syllable-level entrainment within the speech stream.
4. Rhythmic entrainment is related to phonological awareness and therefore should be related to reading development, since it is related to phonological awareness.

5. A training programme based on rhythmic entrainment, that does not necessarily involve music, will be equally effective in improving phonological awareness skills with pre-school children.

From these hypotheses we are led to research questions that have to be answered within the design of the testing protocol. The testing protocol should allow us to measure the accuracy of entrainment in young typically developing children and explore its relations (if any) to language and phonological development. The formulation, details and means of measurement within the research protocol are discussed in this chapter.

Research Questions

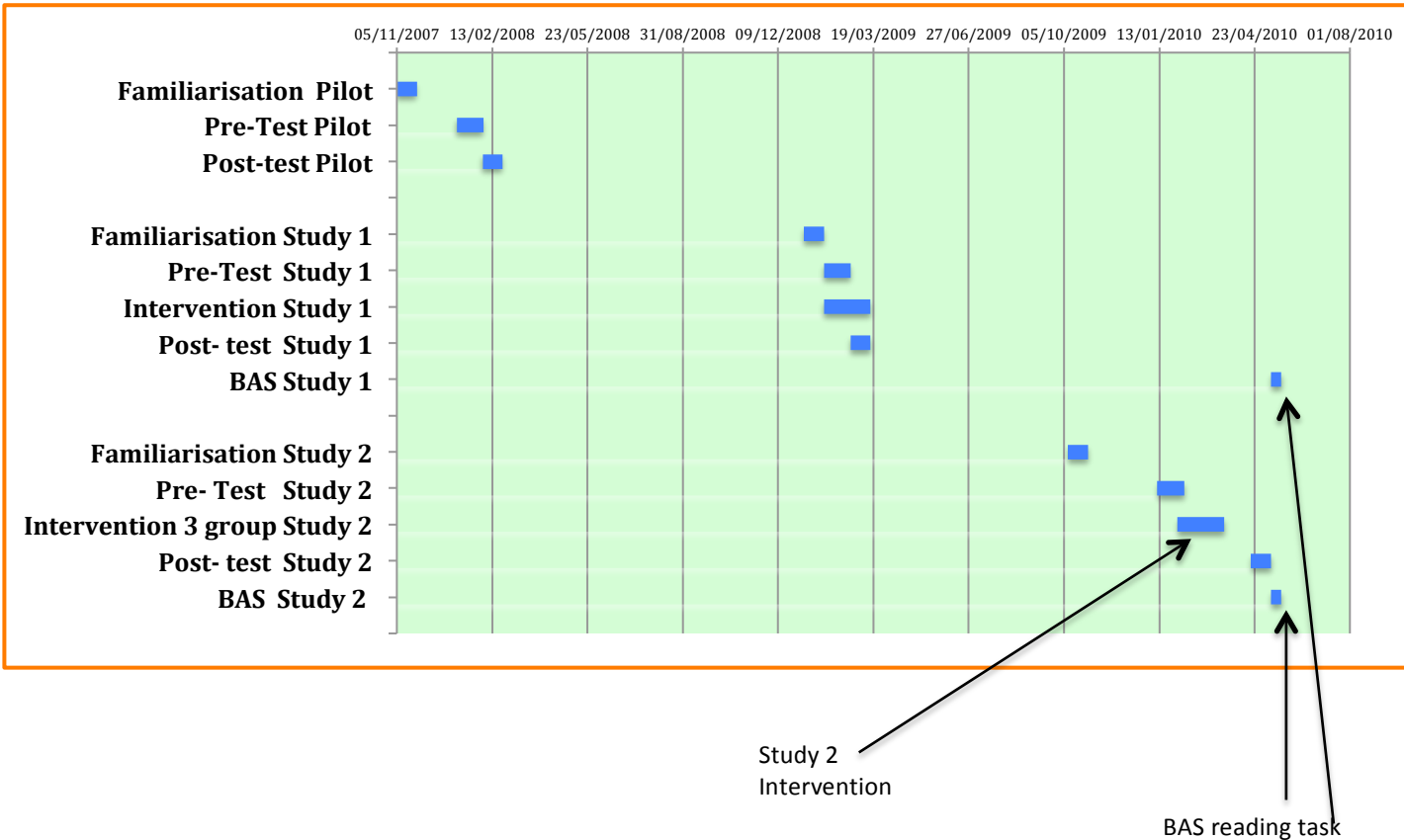
1. Is there an optimum pulse rate within music that helps children to entrain to a beat and is it dependent on the quality and type of stimuli.
2. Will accurate metrical perception predict improved phonological learning?
3. Are there auditory and temporal processes that are used in perceiving both music and language?
4. Can auditory and temporal processes enable the extraction of periodic structure and rhythm, and can we assume that individual differences in the quality of these basic auditory processes affect the development of language and musical cognition?
5. If rhythmic structure and temporal isochrony is more overt in music than in language and enables the accurate segmentation of syllables and words from the speech stream, is it possible that musical interventions could improve reading skills in children with developmental language disorders. (Goswami 2011, Overy, 2000, 2003; Forgeard et al., 2008)?
6. Is it possible that the rhythmic attributes of rhythmic speech are as effective as those in music in helping children to segment the speech stream?
7. Can we gain a greater understanding of the skills required to process phonological information, and become more able to decode the language in readiness for reading through an increased understanding of the relationship between the rhythmic properties of speech and music?

3.1. Overall Design of the Study.

Much of the methodology and procedures are common to both studies, but this chapter describes, specifically, the participants, recruitment, and measures used in the investigation in Study 1 with the first group of participants. Data collection, data analysis, and methods used in the study to investigate the research questions concerning the impact of rate and musical content are presented. The procedures for testing the children are then described.

In the following chapter the results from this study are reported and in chapters 5 and 6 the methodology and results from Study 2 are presented.

Table 3.1.1 Gantt Chart for Study Timelines – Pilot, Studies 1 and 2



The Gantt Chart (Table 3.1.1) shows the timeline of the three studies considered in the thesis (including the pilot study). The visual representation

shows that the BAS reading task was done at the same time for both Studies 1 and 2. It also shows that in Study 2 the three group intervention detailed in Chapter 8 was a discrete module in the research. Further details of the exact nature of the timeline for each study are given in Tables 3.5.2 and 8.1.2.

Study 1 (Year 1)

3.2 Participants

In year 1 of the study 120 participants were recruited from the Reception classes in seven schools. This was a convenience sample of, initially, 67 boys and 53 girls and testing took place when the children were aged between 4 years 6 months, and 5 years 1 month and commenced in February 2009.

The seven ‘first schools’ were in a rural part of Northumberland, and were chosen because they had different demographic characteristics, different educational environments and standards as defined by their most recent Ofsted²⁷ reports (Table 3.2.1). The principle difference was the varying class sizes in each school that ranged from 7 children to 20. Another characteristic of school 4, with the lowest on-entry scores, was that the reception children were taught with nursery children in the morning, and only had a separate curriculum in the afternoon. The children in this group had received less literacy training than the other groups. Nevertheless all the reception teachers were focused on the same method of teaching synthetic phonics – “Letters and Sounds”- as recommended by the National Strategies (Primary) for the Department for Education and Skills (DfES) 2007.

The schools had a stable population and only one child left during this phase. The number of participants was reduced to 96 when one school withdrew its support after the WPPSI-R (IQ) and music tests were nearly completed. Three additional children were removed from the list of participants:- a boy was taken ill; a girl with severe learning difficulties could

²⁷ Ofsted = The Office for Standards in Education, Children's Services and Skills. The services Ofsted inspects or regulates include: local services, childminding, child day care, children's centres, children's social care, Cafcass, state schools, independent schools and teacher training providers, colleges and learning and skills providers in England.

not complete any language based tasks, and one other girl left school. The participant numbers for the final analysis in Study 1 was 93.

Table 3.2.1 Ofsted and 'On-entry' data for the 6 participating schools in Study 1

School	Number on Roll	Number in Reception	Foundation Stage Profile Score	FSP Comment
1	52 (2007) <i>"Children "start school with average levels of development"</i>	11	49	Outstanding
2	71 (2008) <i>"Children start school with abilities " in line with with age related expectations in early reading"</i>	16	41	Good
3	99 (2009) <i>"Children start school with abilities "broadly typical for their age"</i>	20	40	Outstanding
4	107 (2006) <i>"Children begin school with low ability, especially in language"</i>	14	37	Satisfactory
5	147 (2007) <i>"Children's starting points in Reception are below expected levels"</i>	20	47	Good
6	(<i>"a school with some social and economic disadvantages"</i> <i>Number of pupils with learning difficulty is above average</i>) 83 (2009)	15	43	Satisfactory

(Please note these inspection dates were correct at the time of testing)

3.2.1 Participant recruitment

Ethical approval for this project was granted by the University of Cambridge Psychological Research Ethics Committee (application no. 2007.51)

Because of the nature of the research a full Criminal Records Bureau enhanced disclosure was obtained from Northumberland County Council to allow me access to children in all Northumberland schools dated 6th of July 2007 (001167602012). (appendix A)

Access to schools was obtained through personal contact, and access to children required consent forms to be obtained from all parents. In the letter requesting access to the children the research programme was clearly

outlined, explaining the times children would be withdrawn from class and the nature of the testing.

(Letters to schools and parents are given in appendix B.)

The following paragraphs explained the ethical procedures:-

Confidentiality/Ethical Approval

“All data will be identified by a code, with names kept in a locked file. Results are normally presented in terms of groups of individuals and will be presented at conferences and written up in journals. If any individual data were to be presented, the data would be totally anonymous, without any means of identifying the individuals involved. This project has been approved by the Cambridge Psychology Research Ethics Committee.

A consent form is attached to this letter. If you are willing for your child to take part in this study, please complete it and return it in the addressed envelope provided to your school. If you would like any further information, please do not hesitate to contact John P. Verney at jpv28@cam.ac.uk; by telephone at 01670 787702, or via the school.

Please note that you may withdraw from the project at any stage without explanation.”

All visits were arranged at times to cause least inconvenience to the schools.

In this section, I first consider the design of the music tasks, how they were recorded and how data were collected from the computer programme. Then I describe each music test and how it was presented to the children. The final part of the methodology section describes the psychometric testing protocol.

3.3 Music Measures

The design of the tests necessitated the use of 3 kinds of rhythmic stimuli:-

- A simple auditory sound source that could maintain a given pulse rate – mechanical, electronic, and computer generated metronomes were used;
- Instrumental music with an isochronous (constant) pulse rate;
- Songs with and without instrumental accompaniment.

All the instrumental music had many of the qualities associated with sung music, such as matched phrase lengths, and melodic contours suitable for singing, and indeed some of the music that was originally played to the children, so they could drum along with its beat, was used in its original form as music with words (a song) during the music training programme.

3.3.1 Design of the music tests

The music for the studies was composed or arranged, recorded and edited by the author. All the music had been composed for young children, some as young as 9 months old, to stimulate language and communication development and tested with many thousands of children²⁸ over many years. All the music had a well-defined musical structure based on predictable harmonies in simple duple or triple time (Koelsch, 2005 and Hannon & Trehub, 2005). The harmonies used to strengthen accent awareness were always chords V to 1 (perfect cadence) (Bergeson and Trehub (2006) (Figure 3.3.1) and rhymes were always placed on strongly stressed beats of the bars. The underlying rhythm was always very predictable in accent, stress and

²⁸ At one point in my advisory teaching role I was working with two or three hundred children a week, so over a period of 15 years the numbers of children I visited was certainly in the many thousands.

harmonic progression. Added interest was given to the compositions by unusual instrumentation, chromatic harmonies and counter melodies, but these never affected the simple cadences and principle stresses on target notes and rhymes (see enclosed CD and appendix C).

Even though the melodies of the songs were sometimes syncopated²⁹ (Figure 2.4.5 *Mickey the Mouse*) in order to make the music match more natural speech patterns, the underlying rhythm was always very predictable in accent, stress and harmonic progression. The musical stimuli for the tapping tests were devised from songs (see appendix D for original material). They were all composed within defined parameters:

- The speed was set and underpinned by a metronome beat;
- Interest was added to this beat by a simple percussion track which further accented the principle beats in the bar (measure);
- A bass line was added to emphasise the harmonic movement;
- In some melodies a simple chord structure was added to give the harmony more definition;
- The melody line was added which supported the words in the original composition;
- The children found them attractive to listen to.

The singing tests were generally in an appropriate vocal range of middle C to G (261 hertz – 392hz) and at no time did there appear to be a problem with the children singing along to an adult male, whose voice was an octave lower (130 – 196hz).

Figure 3.3.1. Simple Harmonic progressions in Music tests. Fly a kite

John P. Verney

$\text{♩} = 60$

²⁹ Syncopation is where the melody has a different accented note to the underlying harmony or rhythm.

A range of beat-based drumming and singing tasks were devised at four temporal rates, 400 ms (2.5 Hz, 150 bpm), 500 ms (2Hz, 120 bpm), 666 ms (1.5 Hz, 90 bpm) and 1000 ms (1 Hz, 60 bpm,) (*all described fully below*). These pulse rates were selected based on prior work on rhythmic entrainment in developmental dyslexia (Thomson and Goswami, 2008) and SLI (Corriveau and Goswami, 2009), and were also chosen to lie within the region of greatest pulse salience in Western music (Thaut, 2005).

3.3.2 Recording and calibration of the music

The experimental tasks were designed to measure rhythmic entrainment and synchronization at different temporal rates and to measure temporal accuracy in singing. The songs and music were created using an electronic keyboard and ‘Sibelius’ music publishing software, using either the orchestral midi sounds found in ‘Native Instruments Kontakt Gold’ or the general midi sounds from a Yamaha Tone Generator (TG33). The open source software ‘Audacity’ was used to programme a registration track from which the accuracy of children’s rhythmic entrainment could be calculated with millisecond (ms) precision. A further advantage of this software is that it allows one to take existing digital music (instrumental backing tracks) and transfer them into a program on which one can record a master vocal track. If the original backing track is recorded at a slightly different speed then it can be manipulated into synchronisation with the target speeds. ‘Audacity’ can detect very low auditory signals and enhance them for measurement. If a child sings into the microphone at a very low level it can be difficult to hear their responses so the signal needs boosting. This results in a lot of background noise that must be eliminated. Audacity performs this task well and allows recording and analysis of near whispers. A personal computer microphone (Gembird) was used to transfer information from the bongos and the children singing into digital form in the computer. Certain tracks needed to be transferred from existing CD recordings by creating ‘WAV’ files. ‘Adobe Audition’ (2003 version) performed this task before the files were transferred back into Audacity.

All tests were recorded on the same computer so that any errors associated with different hard drives or sound processing module speeds were eliminated. Care was needed to ensure that there was synchronisation between the registration track and the recording of the children's performance. The 'Rock' laptop used had a fast hard drive (7200 RPM) and recorded accurately throughout the length of each trial, but adjustment needed to be made on every analysis to account for latency³⁰ inherent in the software and processing during recording.

Initially all music was composed and edited on a desk-top PC with an Audigy 4 (Creative) Soundblaster external soundcard, and latency controlled by ASIO drivers. This software eliminates most latency problems and accurate recording times can be taken, even when the music has complex sounds that need more processing power.³¹ Unfortunately this equipment could not be taken into a school environment where one could never be sure where the recording was to take place, or whether you would have to move rooms.

When recording with a laptop in the field it can be difficult to gain accurate and consistent timing, because each environment can alter the way the computer processes recordings. Even electricity power can vary. I recorded in one room where power was reduced when the heating system came on. At no time can recording take place using battery power.

Over the three -year period of recording the amount of recalibration required increased by 20 milliseconds. This could have occurred because of the age of the laptop, and the increasing amount of information stored on the machine. Because of these inconsistencies it was necessary to have a method to synchronise the recording and the registration track from which the timings were taken for each musical test. The children were always given at least 8 beats from which they could entrain before they started to tap. These taps were recorded live and could then be adjusted into accurate synchronisation with the registration or 'click' track.

³⁰ Latency is the delay associated between the actual sound of recording and the computer response.

³¹ A simple signal, such as a metronome, needs very little processing power, but any complex synthesised sound such as those used in the recordings of the song accompaniment requires more processing, and latency can increase.

At the start of each analysis the entrainment beats found in the children's recording are placed in line with the registration track, and then all beats in the rest of the recording are aligned and can be measured accurately within 1 or 2 milliseconds. (Figures 3.3.2 and 3.3.3)

Figure 3.3.2

This diagram shows a registration track and the recording out of synchronization before re-recalibration

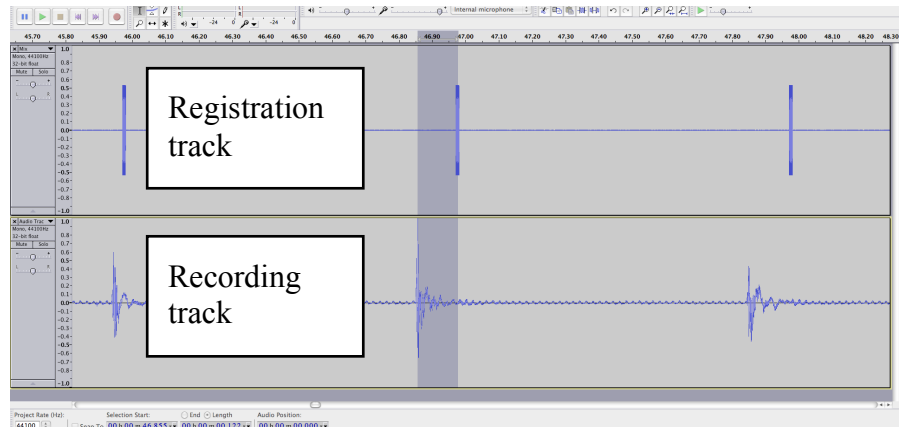
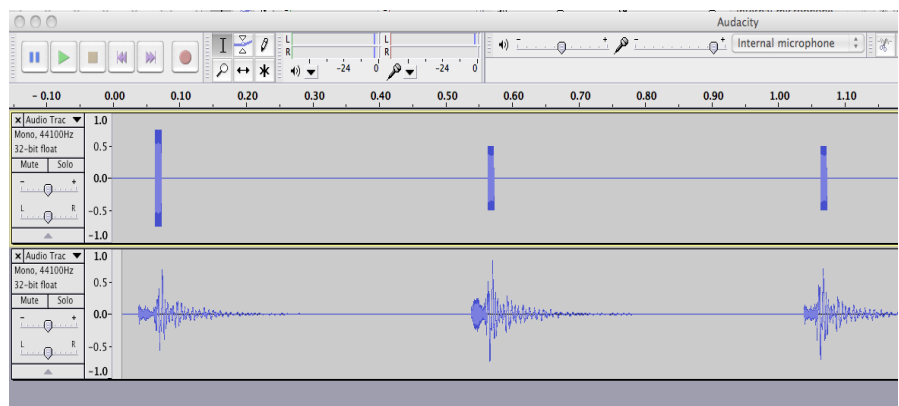


Figure 3.3.3

This diagram shows a registration track and the recording synchronized – any deviations can now be measured



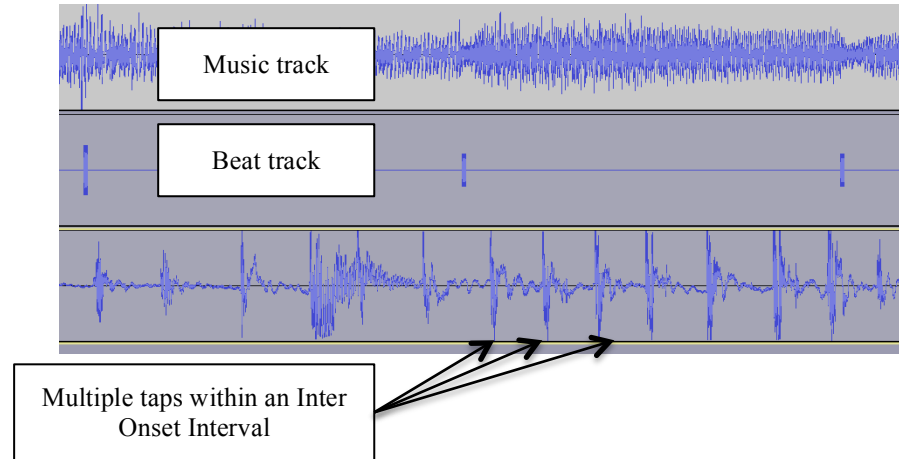
3.3.3. Analysis of the children's recording

The method employed in this study to measure the accuracy of the children's tapping or singing using only Audacity is very time-consuming but it does give an accurate result of the asynchrony of each beat from the ascribed linear time scale within each musical task. The drumming and singing behaviour of young children is often out of phase, but the wide variations in synchronization are easily seen visually in this programme and can be accommodated in the analysis. The only time a point of

synchronization cannot be analysed is if there are multiple taps within the beat (Figure 3.3.4).

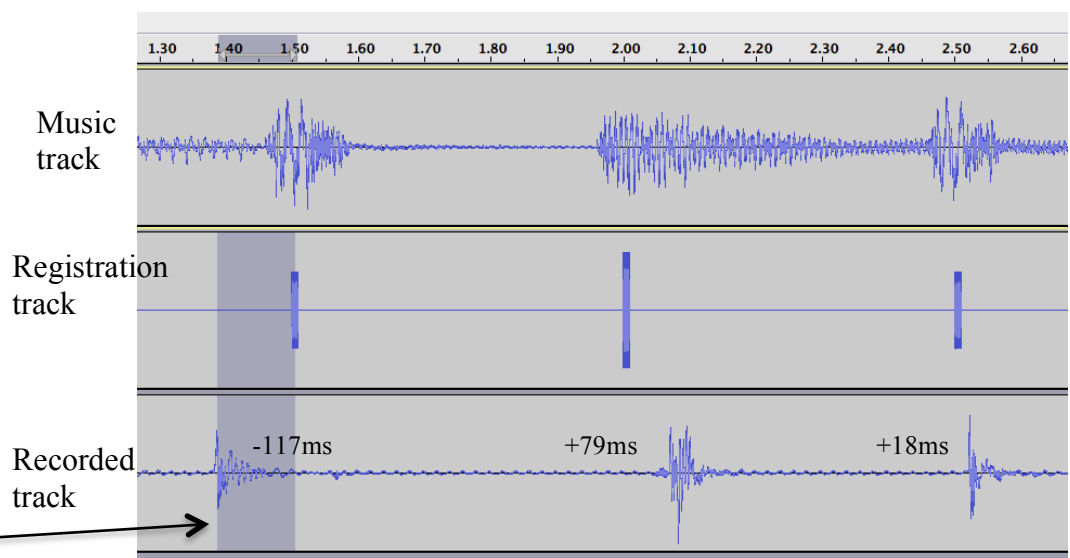
Figure 3.3.4

This diagram shows the child playing multiple taps within the IOI – no score can be given.



Further confirmation of the accuracy of the raw data scores was achieved when study 2 data were reviewed to discover the scores for analysis that took into account whether the children anticipated or delayed their responses to the beat. The revised scores for each test were always within one or two milliseconds of the original analysis. Further confirmation of the validity of the method came from comparing the results in both studies. Analysis of the data comparing the drumming to metronome and drumming to music in studies 1 and 2 showed no significant differences ($p = .13$ and $p = .22$ respectively). (See section 6.1 for full analysis).

Figure 3.3.5
Method of recording accuracy of children's performance. The shaded area is created in Audacity by using the computer mouse.

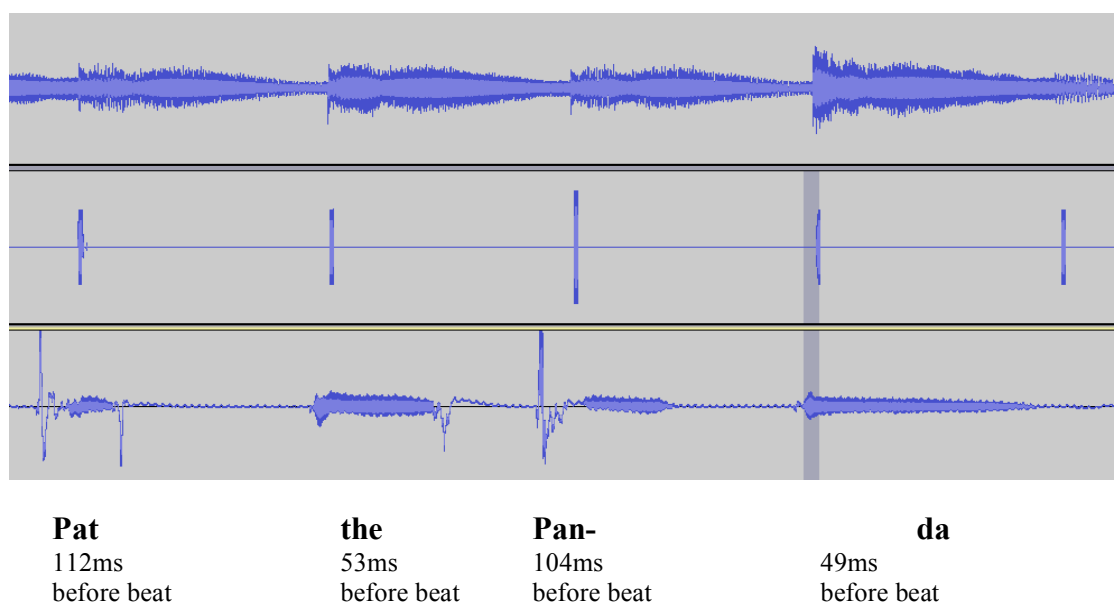


Once the recorded tracks of the children are synchronized with the registration track then a very simple method of checking the accuracy of their performance is used. The computer mouse draws a shaded area between the centre of the registration track beat marker and the point of peak activity in the children's recorded bongo tap. The programme then gives a measurement defined by the shaded area in milliseconds.

The three points illustrated in Figure 3.3.5 have a deviation from the registration points of 117, 79 and 18 milliseconds. The task score (the variation from the mean) would be computed from the total of 16 points within each test. (*Note that the music track is in synchronization with the registration track.*)

The same method can be used to analyse the singing data. In line with previous studies designed to measure the accuracy of amplitude envelope rise time (Thomson and Goswami, 2008; Corriveau and Goswami, 2009) analysis of the child's synchronization was taken from the consonant immediately before the vowel.

*Figure 3.3.6
Measurement of
synchronisation
in a song
recorded in
Audacity. The
data were
collected from
the consonant
before the vowel
sound.*



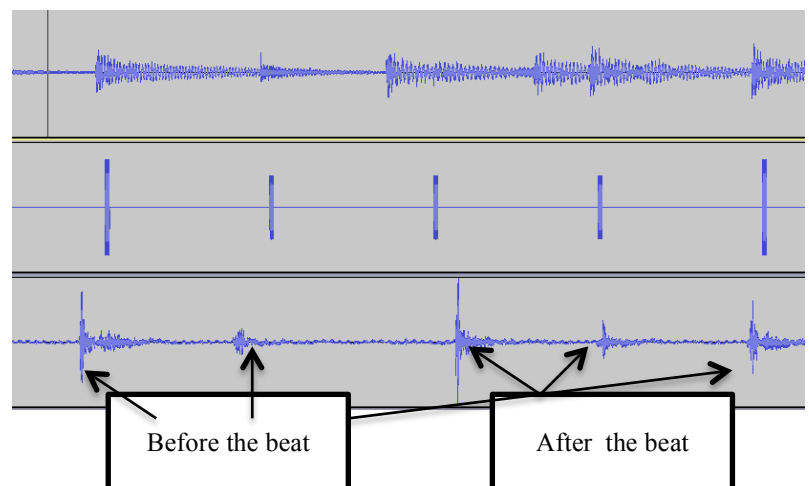
In Figure 3.3.6 the spectrograph shows clearly the onset of the sound of the letter ‘P’ in Pat and Panda, and these consonants give clear markers from which to measure the accuracy of the synchronization. The onset of the sound of the letter ‘d’ is also clear (shaded from the onset rise). Because the music is defining the position of the words we can also measure ‘the’ with accuracy from its onset rise even though the word starts with a fricative. (*Note again the way the music is in synchronization with the registration track.*)

Throughout the experiments this method was always used, so that consistent comparisons were made across across the whole study.

Adult participants generally anticipate the beat in a musical task, especially at the slower speeds (Repp, 2001) but Figure 3.3.7 shows that there can be variations in their synchronization - sometimes anticipating and sometimes following the established pulse. The ‘Audacity’ files’ visual representation of the acoustic signal shows this clearly and one can calculate the mean difference from the point of synchronization by noting during the data analysis whether the tap is before or after the point of synchronization.

Figure 3.3.7

This diagram shows how a child can both anticipate and follow the beat within a tapping task.



3.3.4 The Music Tasks

(All played to the children through the laptop speakers. The children's responses were recorded for analysis in 'Audacity')

a) Metronome Task

Here the children were presented with a computer simulated metronome ticking at one of 4 rates with an Inter-Onset Interval (IOI) of either 400 ms, 500 ms, 666 ms, and 1000 ms. They had to keep time with the beat on a pair of Bongo drums (playing with two hands). Overall the task comprised 24 beats. However, accuracy of rhythmic entrainment was measured using the final 16 beats only – the first 8 beats allowed the children to entrain to the pulse rate.

b) Beat alignment to music

In Phase 1 of the study there were two tests given to the children to test their beat alignment. The first test was initially called the 'paced' condition.

Here the children used the Bongo drums to play in time with 4 simple tunes without words written by the researcher. The underlying pulse rate in the music was either 400 ms, 500 ms, 666 ms or 1000 ms. The different musical pieces are depicted schematically in Table 3.3.1. Two tunes were recorded at each pulse rate to ensure that the specific musical content³² of a piece per se did not affect results. Half of the children received one set of 4 tunes, and the other half of the children received the second set of 4 tunes. A 2 x 4 (Tune Set 1 and 2: Rate: 400ms, 500ms, 666ms, 1000ms) ANOVA showed that there was no significant difference between the performance of the groups ($F, 102 = .34, p = .56$).

A second test using the same sets of music was named the 'unpaced' condition. As part of an experiment to investigate a link between timing precision and rhythm in developmental dyslexia (Thomson and Goswami (2008) 48 10 year old children (25 dyslexic and 23 typically developing) were given rhythmic metronome tasks at three rates (400ms, 500ms and 666ms).

³² The music chosen was mainly in 4/4, but 2 tunes were in simple compound time 6/8. Most were in a genre typical of nursery rhymes, but for the 400ms task, the 'Race' song was more jazzy.

The tasks were in two conditions. The first corresponded to the beat alignment task with metronome described above which they described as tapping in a ‘paced’ condition, and a second task where the children had to continue tapping after the metronome had stopped:- the ‘unpaced’ condition. Even though they found that all the 10 year old children found this task very difficult it was replicated with this group of younger children. In the metronome task the children heard 24 beats at each pulse rate, and then were asked to continue tapping for a further 8 after the sounds stopped. The data were collected from the last 8 beats heard (‘paced condition’) and then the next 8 beats after the sounds stopped (‘unpaced’ condition’). In the beat alignment task with music the children were once again divided into two groups and given different music at each of the 4 pulse rates. The data were collected from the last 8 beats they heard, and then the 8 beats after the music stopped.

c) **Beat Alignment - Singing**

Two kinds of singing measures were used. First, the children sang the “Hello” song along with a recording of the researcher’s voice and a simple chime bar based musical accompaniment (which they had already practised during the ‘Familiarisation’ sessions, see below) at the 4 different rhythmic rates. A chime bar midi sound was used because it has a distinct start (onset) to its sound as it simulates the beater hitting the metal bar. This helped the children to synchronise accurately with the pulse rate of the song, and enables accurate measurement of the children’s deviations from the beat. Beat accuracy at each rate was timed for the second phrase in the song, and variety was introduced by changing the name of the person being sung to (“Hello Mr Verney”; “Hello Pat the Panda” etc. – see figure 3.5.1). This measure is hereafter referred to as *Singing in Time*. Second, the children were given a familiar nursery rhyme, and were asked to sing along to it with a recording of the researcher’s voice. The children were also asked to contribute certain rhyming words to the song by themselves, on cue (the researcher stopped singing). The words to be sung were always the final word in a musical phrase, and there were two conditions for this *Singing the Rhyme* measure.

Table 3.3.1. Schematic overview of the different music and songs in Study 1

Drumming Tasks in Study 1					
Practice piece	Play along with the ‘Sputnic Song’ (666ms)				
Beat alignment to a metronome beat	Task 1	Drumming at 4 pulse rates / each rate has 24 beats.			
		500ms	400ms	666ms	1000ms
The sample is divided into 2 groups each drumming to a different set of pieces.		Group 1		Group 2	
Beat alignment to music	Task 2	Marching through the Jungle		Rover Had a Rag	500ms
	Task 3	Music Day		The Race Song	400ms
	Task 4	The Soldier’s Song		Butterfly	666ms
	Task 5	Snake		Kite	1000ms
The same tasks above were given to both groups of children, except the music was changed – Group 1 were given the music initially presented to Group 2 and vice versa.					
The children were then asked to continue drumming for 8 beats after either the metronome or music tasks became silent – ‘the unpaced condition’					
Singing Tasks					
Practice Piece	Play and sing along with ‘Mr Verney’ song (600ms)				
Singing in Time musical phrase with a chime bar accompaniment (Syllables match notation – except on final word)	Task 6	Can the children sing along counting the number of syllables:- 1 2 3 4 5 6 (match)			500ms
	Task 7	Can they sing and play “Hello Pat the Panda” (match)			666ms
	Task 8	Can they maintain the rhythmic structure of the song with syllable names .eg “Hello Mr Dinosaur” (mismatch)			1000ms
	Task 9	Can they maintain the rhythmic structure of the song a single syllable name. “Hello Mister Duck” (mismatch)			400ms
	(+Music)		(-Music)		
Rhyme Tests +Music = with accompaniment	Task 10	Hickory Dickory	Task 14	Hickory Dickory	1000ms
	Task 11	Twinkle Twinkle	Task 15	Twinkle Twinkle	666ms
- Music = with voice only	Task 12	Baa Baa	Task 16	Baa Baa	400ms
	Task 13	Miss Polly	Task 17	Miss Polly	500ms

The *Singing the Rhyme*, + Music condition required the child to contribute the final-phrase rhymes when the researcher was singing along with a fully orchestrated musical accompaniment.

The *Singing the Rhyme*, -Music condition required the child to contribute the final-phrase rhymes when singing with the researcher using voice alone (no musical accompaniment during the entire song). The aim was to see whether it was easier for young children to keep in time with the beat with voice alone or with music and voice together (which provides a richer musical experience). Four familiar nursery rhymes were used for the *Singing the Rhyme* measure, each presented twice at one pulse rate only (400 ms, 500 ms, 666 ms, 1000 ms, see Table 3.3.1).

Temporal accuracy of singing the second phrase (Singing in Time condition) or of contributing the missing words on time (Singing, +Music versus -Music conditions) was recorded in ms.

3.4 Experimental Tasks (see appendix E)

In addition to the music tests the children were given standardized cognitive ability and reading tests, and experimental phonological awareness tasks. Data from UK national screening measures for linguistic and cognitive development were also available from the children's schools (the Foundation Stage Profile, see below).

3.4.1. Standardised I.Q. and Reading Tests

These comprised the Wechsler Preschool and Primary Scale of Intelligence III (WPPSI, Wechsler, 1991; designed for the age range 2 years 6 months – 7 years 3 months), and the British Ability Scales single word reading test for English (BAS, Elliott, Smith & McCulloch, 1986).

i. Two subtests of the WPPSI were administered, selected because together they provide an estimate of full-scale IQ. The subtests were Information (verbal ability) and Picture Completion (nonverbal ability). In the Information subtest, children had to identify a picture from alternatives

according to the question asked. An example is “Look at these pictures. Point to the one you cook with”, with a choice of pictures of a fridge, table, cooker, sink, shower and chair. Questions became increasingly difficult and more verbally demanding, e.g. “Show me your nose. Touch it” – to “Where does the sun set?”. For the Picture Completion test the children were shown 28 pictures of well-known objects or people. Each picture had something missing (e.g., a teddy bear without a head). Scores were then pro-rated to give a full scale IQ estimate following the directions in the manual.

ii. The BAS³³ is an untimed measure of children’s word reading accuracy normed on a UK population, and presents single words graded in difficulty for reading aloud. Reading standard scores and age equivalent scores were calculated as directed by the manual.

iii. Word Test Recall (Pickering and Gathercole 2001) This test comes from a much longer battery and is included because it has an 80% reliability coefficient and a standardised score for children aged between 4 years 7 months and 5yrs 6 months. The test assessed the strengths and weaknesses of the child’s working memory profile that can help gain understanding of the learning difficulties faced by the child. The examiner reads out a list of words that the children then repeat. The number of words in each trial increases from 1 to 7 with six groups of words in each trial. The children are scored according to the number of correct trials and are also given a span score if they score 4 out of each 6 correct. It is suggested that the words are said by the examiner at interval of one word every $\frac{3}{4}$ second.

iv. The Foundation Stage Profile is a baseline screen devised for state schools in the United Kingdom that is first administered by teachers in either the last few weeks of Nursery education (age 4 years) or within the first 6 weeks in the Reception class (age 4.5 to 5 years) and then generally reviewed every term. Overall 13 measures are assessed on a nine point scale, with the expectation that point nine will be reached at the end of the Reception year, as the child progresses to full time statutory education at the age of 6 years. The profile is not strictly standardised as it relies on teacher judgement in following the administration rules outlined in the documentation. However,

³³ The British Ability Scales Word Reading Test (Elliott, Murray and Pearson, 1977)

the overall FSP score provides an additional measure of a child's general ability as perceived by their teacher, and the subcomponent 'Communications, language and literacy' (CLL)³⁴ provides a score that might be expected to correlate with a child's phonological awareness skills.

<i>Table 3.4.1 Foundation Stage Profile (DfES 2003)</i>	
Personal, Social and Emotional Development	Mathematical Development
Dispositions and Attitudes	Numbers as labels for counting
Social Development	Calculating
Emotional Development	Shape Space and measures
Communications Language and Literacy	Knowledge and Understanding of the world
Language for communicating and thinking	Physical Development
Language for communicating and thinking	Creative Development
Linking sounds and letter	
Reading	
Writing	

To enable comparison between the overall FSP score and the CLL score, both are here expressed as a percentage of the maximum possible score (hence 50% would show average progress given that the children were tested in the middle of the Reception school year [February]).

3.4.2. Phonological Tasks

These comprised two tests of rhyme awareness, and two tests of syllable awareness. As the children were very young, I used both picture-based tasks and oral tasks to measure their phonological awareness.

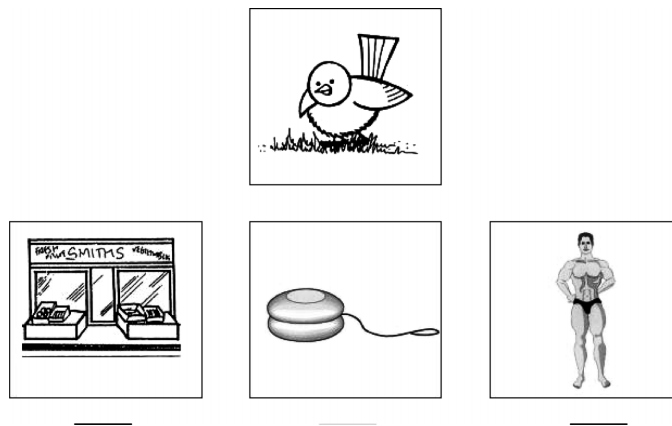
a) Rhyme Awareness, Picture Task. This task was taken from James et al., 2005. Children were shown a cue picture and three alternative choice pictures. The researcher named the pictures to make sure the young children knew what the pictures were. They were then asked to select the alternative that rhymed with the cue picture (e.g., *key*, *sea*). There were 24 trials in total.

b) Rhyme Awareness, Oral Task. This was the Oral Rhyme Test from the PhAB (Phonological Awareness Battery, Fredrickson & Frith,

³⁴ In the analysis used in this research the writing component within the CLL was not used.

1997). Children were asked to identify which two of three words sounded the same at the end (e.g., *sail, boot, nail*). There were 21 trials in total.

c) Syllable Awareness, Picture Task. This task also came from James et al., 2005. Children were shown a cue picture and three alternative choice pictures. As in the rhyme task the children were also told what the pictures were. They were asked to select the alternative that had the same number of syllables as the cue picture (e.g., *duck: shop, yoyo, body*). There were 27 trials in total.



d) Syllable Awareness, Oral Task. This task was adapted from Treiman and Zukowski (1996). Children were presented with pairs of words spoken by a puppet, and had to tell the experimenter whether the word pairs shared a syllable or not (e.g., *compete, repeat*). There were 40 trials in total.

3.5 Procedures in Study 1

3.5.1 Familiarisation pre-test music activities

Prior to receiving the experimental tasks described above, the children participated in a series of familiarisation pre-test music activities with the researcher in their class groups in order to become comfortable with the experimenter and the tasks. This was achieved by the researcher replacing the class teacher during music lessons. First, all children were provided with mini-maracas and were taught to tap them on the non-holding palm to the rhythm of some music. The maracas



could also be used as substitute microphones to help the children sing like a ‘rock star’. Chime bars were introduced to help the children with pitch sensitivity. The children were introduced to singing into a microphone and to a big cuddly toy – ‘Pat the Panda’, who was used as the catalyst for learning songs and who later also accompanied them to the testing room when they received the experimental assessments.



The familiarisation sessions introduced children to the idea of adapting rhythmic tapping to different speeds, by the use of an old fashioned metronome, and to the song structures to be used in the experimental assessments. The children were introduced to the Bongos by demonstrating what they sounded like and how they are played with two hands. Bongo’s were chosen instead of a drum machine or touch sensitive electronic pads, because it was felt that the children would be more attracted to their characteristics and they would be more familiar with them. The children then learned to sing an introductory song – “Hello Mister Verney”. The song was written to have simple pitch structure (based on 3 notes, C, D, E, with each of the first 3 phrases sung as six notes at each consecutive pitch, and the final phrase sung as two notes descending down each pitch). Every syllable matched a note in the song: “*Hello Mr Verney; Hello Mr Verney; Hello Mr Verney; How are you today?*”. The children were given the notes to play on chime bars, identified by colour coding. After learning “Hello Mister Verney”, they progressed to learning the same tune as “Hello Pat the Panda”. Finally, they learned to sing the digits 123456, so that each number (a monosyllable) matched the notes of the song (Figure 3.5.1)

A rhyming song was introduced next (see Figure 3.5.2):- *Mickey the mouse, Mickey the mouse; He plays music all round the house. Mickey the mouse, Mickey the Mouse; He plays music inside the house.* A recording of this song was first played without words and the children were shown how to play their mini-maracas in time to the music. The song could be repeated many times, giving the children the opportunity to stop and start their maracas on cues given by the researcher.

<i>Table 3.5.1 Musical activities used in the familiarisation pre-test sessions</i>		
Hello Mr Verney	Singing	Chime Bars
Tapping to Metronome	Tapping	Metronome
Hello Pat the Panda	Singing	Chime Bars
Counting to 6	Singing	Chime Bars
Mickey the Mouse (a)	Singing	CD Track
Mickey the Mouse (b)	Tapping	Mini Maracas
Bye Bye Mr Verney	Singing	Chime Bars

Figure 3.5.1

Hello Pat the Panda

Hello Mister Verney

Hel - lo Pat the Pan - da, Hel - lo Pat the Pan - da,
Hel - lo Mis - ter Vern - ey Hel - lo Mis - ter Ver - ney
1 2 3 4 5 6 1 2 3 4 5 6

Hel - lo Pat the Pan - da How are you to - day.
Hel - lo Mis - ter Vern - ey How are you to - day
1 2 3 4 5 6 That was ver - y good

Figure 3.5.2

Mickey the mouse

Mick - ey the mouse; Mick - ey the mouse; he plays mus - ic all round the house
Mick - ey the mouse; Mick - ey the mouse plays the mus - ic in - side his house

The sessions ended with a “Bye Bye Mister Verney” song using the same tune as “Hello Mister Verney”. This time the children performed actions to mirror the rhythm of the song – whilst sitting they tapped the floor 6 times for the first line, tapped their knees for the second line, and then waved their hands in the air for the third line, then back to tapping on the floor for the last line.

3.5.2 Testing Environment

The tests were administered in two 10 – 12 minute sessions:- the first for the bongo tapping, and the second for the singing tests. Before the recorded tapping tests took place the child and researcher played along to a practice piece to get relaxed and focused on the tasks (Sputnic Song).

Each music test started by looking at the picture. According to what task was to be undertaken the tester said “Let’s play along with the elephants marching in the jungle” or “Let’s tap along with the butterfly”. All the music activities were designed to put the children at their ease so they would perform at their best during the testing procedures. The cuddly toy they brought to the testing room was used as a graphic in all the material they saw when they were confronted with new tasks. This was incorporated into their music ‘Bongo Phonics’ book, (appendix F) with its colourful pictures (figure 3.5.3). It was placed on a music stand in front of the children so they had something to look at, and could turn the pages between tests. (Figures 3.5.4 and 3.5.5). This helped the testing process because, whilst the child turned the page, the researcher could find the next test on the computer. The book was also a barrier, preventing the child from being distracted by the computer screen.

*Figure
3.5.3*

*Art work
from Bongo
Phonics
Book*

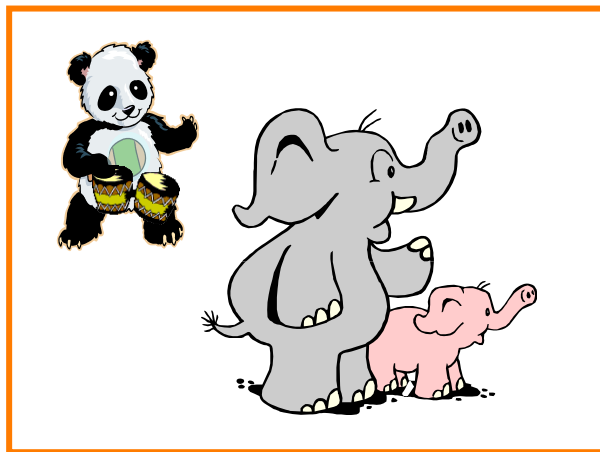


Figure 3.5.4 Playing the bongos

Figure 3.5.5 Singing tests



The familiarisation pre-test music sessions allowed the children to experience the kind of musical tasks they would encounter in the testing protocol so they would be confident and happy to take part in the testing procedures. The testing time for each child on all tests was generally 10 to 12 minutes per week. The testing environment was always in a room chosen by the headteacher to conform with the schools' policy of child protection. It was generally in a quiet place near the classroom, to minimize time lost between participants testing times.

In Study 1 either after or before the testing had taken place the researcher took a 20 minute music session with the class each time he visited the school. (Table 3.5.2)

Twelve months after the last visit to the schools (March 2009) the children's reading was tested using the BAS test described above. It was completed at the same time as the children in Study 2 had completed their post-tests so that a comparison could be made between phases.

Table 3.5.2 Study 1 Timetable commencing January 2009				
Weeks	Comments	Test Time		Music Session
1 - 3	A visit each week to the schools for the familiarisation pre-test lessons	30 minutes		At either the end or beginning of each testing session within each school all the children were gathered together for a music session
4 - 6	Assessment Testing	12 minutes	one	
	Music Tapping Test	day		
	Singing Test	10 minutes	one	
	WPPSI	10 minutes	one	
7 - 9	Pre-testing	day		
	Oral rhyme and Picture Rhyme	12 minutes	one	
		day		
	Word Recall and Picture Syllable	12 minutes	one	
		day		
	Oral syllable test (+catch up)	12 minutes	one	
		day		
May 2010	BAS reading test	6 minutes	one	
		day		

Chapter 4 Results from Study 1

To compute the analyses SPSS versions 15.0 – 20.00 were used to obtain descriptive statistics, general linear models and correlation/covariance. Statistica was used to obtain ‘Post hoc’ group comparisons and graphic representations.

The results from Study 1 are presented in 3 parts:-

- 4.1 describes the results gained from the analysis of the data collected in both the drumming and singing entrainment tasks.
- 4.2 describes the correlations found between the two entrainment tasks – drumming and singing.
- 4.3 describes the analysis of the music tasks and their correlation with the psychometric and Phonological Awareness tasks.

Table 4.1.1 Participant Details

	Mean	(Standard Deviations)
Chronological age (months)	59.6	(3.4)
Foundation Stage Profile (%)	44.0	(7.1)
Communication, Language & Literacy (FSP subscale %)	41.4	(7.7)
WPPSI (standard score, mean = 100, SD 15)	103.9	(12.8)
Word Recall (standard score, mean = 100, SD 15)	110.9	(15.8)
BAS (standard score, mean= 100, SD 15)	111.4	(15.2)
<i>(Taken 1 year later)</i>		
Rhyme Oral (standard score)	89.9	(13.7)
“ (% score)	[34.2]	(22.8]
Rhyme Picture (% correct)	59.6	(28.7)
Syllable Oral (% correct)	51.6	(34.9)
Syllable Picture (% correct)	30.2	(29.0)

4.1. Results of the Entrainment Tests

Rhythmic entrainment data are presented in Tables 4.1.2 and 4.1.3 for the metronome tasks and the beat alignment to music tasks, both of which used tapping accuracy on Bongo drums as the dependent variable. Singing data are presented in Table 4.1.4 for the 3 singing tasks (Singing in Time; Singing the Rhyme, -Music; Singing the Rhyme, +Music). Any responses that were +/- 2 SD outside the mean response time for an individual child were first removed from the data (2.7% responses removed in the rhythmic entrainment tests and

4.6% responses removed in the singing tests). Performance in each task is shown in terms of mean alignment with the beat in milliseconds. A score of 0 indicates perfect alignment. The scores shown in these tables indicate the children's variations from perfect alignment irrespective of whether their beat was before or after the beat. It is a measure of inaccuracy.

Inspection of the Tables shows that more children completed the tasks and could be given valid scores in the Singing tasks (Table 4.1.4) than in the rhythmic entrainment tasks (Table 4.1.2) (*N* = the second number in square brackets). Task scores were eliminated if more than half the data could not be given an accurate score because the children's performance was unreliable (see Figure 3.2.4 where a child has multiple beats within an IOI).

Overall, the highest number of participants was in the tasks at the 500 ms (2 Hz) rate.

(a) Drumming to Metronome and Music

(i) Beat alignment in the paced condition

Both the metronome task and the beat alignment with music task used Bongo drums, so rhythmic entrainment in the two tasks was compared using a 2 x 4 (Task: Metronome, Music x Rate: 400 ms, 500 ms, 666 ms, 1000 ms) ANOVA. Mean beat alignment in ms was the dependent variable, and missing values in the data were replaced by median scores.

Table 4.1.2. Beat alignment in the 'paced' condition (mean in ms) in the rhythmic entrainment tasks, with median in parentheses and standard deviations and total N in square brackets.

Pulse Rate	400 ms	500 ms	666 ms	1000 ms
Beat Alignment to Metronome	91.48 (88) [31.4, 69]	85.38 (81.0) [36.9, 81]	122.6 (125.0) [49.1, 82]	189.7 (189.0) [82.9, 80]
Beat Alignment to Music	84.1 (80.0) [33.0, 79]	94.3 (95.0) [42.9, 87]	101.7 (95.0) [43.2, 82]	140.5 (130.0) [61.5, 57]

The ANOVA showed a significant main effect of Task, $F(1,92) = 25.2$, $p < .001$, because children were significantly more accurate in the music task than in the metronome task. There was a significant main effect of Rate, $F(3,276) = 140.3$, $p < .001$. The significant main effect of Rate was investigated using Tukey post-hoc tests, and arose because the children were equally accurate at the two faster speeds (400 ms, 500 ms), but then declined significantly in accuracy for the 666 ms rate, and declined significantly again in accuracy for the 1000 ms rate (p 's $< .001$). There was also a significant interaction between Task and Rate, $F(3,276) = 17.5$, $p < .001$. Post-hoc inspection using Newman Keuls post-hoc tests revealed that children were significantly more accurate in the musical task than in the metronome task in entraining to the beat at all speeds except 500 ms (p 's $< .05$). For the 500 ms (2 Hz) rate only, they were more accurate in keeping the beat with the metronome than with a piece of music. For the metronome task, they were equally accurate in keeping the beat at the two faster speeds (400 ms, 500 ms), and were significantly more accurate at these two speeds than at either 666 ms or 1000 ms (p 's $< .001$). For the music task, they were also equally accurate at keeping the beat at 400 ms and at 500 ms, and they were significantly more accurate at these speeds than at 1000ms ($p < .001$). There was no significant difference between the performance of the children in the music tasks at 500ms and 666ms, even though the mean scores suggested that the performance at 500ms was more accurate (500ms – 94.3 ms / 666ms – 101.7ms).

Overall the children's rhythmic entrainment was best at 400 ms and 500 ms. Surprisingly at the 500ms rate there was no significant benefit in terms of temporal accuracy from the richer musical experience because at all other rates the children performed with greater accuracy when drumming to music.

(ii) Beat alignment in the 'unpaced' condition

In the task reported above the children simply had to tap along with the beat to a metronome beat or to music as it was playing - this could be described as tapping in the 'paced' condition.

In the second beat alignment task the children had to continue tapping after the metronome had stopped:- the 'unpaced' condition. The reason behind this task was to see if the children had entrained to the beat and were thus able

to continue tapping at the pulse rate to an internal representation of the beat they could no longer hear.

The data recorded were collected from the last 8 beats heard ('paced condition') and then the next 8 beats after the sounds stopped ('unpaced condition'). In the alignment task with music the children were once again divided into two groups and given different music at each of the 4 pulse rates to ascertain if it was the music that caused any difference in performance rather than the pulse rate. A One-way ANOVA showed that there was no significant effect of different music on the children's performance at any rates, suggesting that any differences were due to the speed at which the music was played rather than the music itself.

The data are presented in Table 4.1.3 and shows that at every rate the children's performance deteriorated as they moved from the paced to the unpaced condition whether drumming to a metronome or to music. At every rate the numbers of children able to participate in the task also dropped as they moved from the 'paced' to the 'unpaced' condition.

Table 4.1.3. Beat accuracy (mean in ms) by rhythmic entrainment task in the 'paced' and 'unpaced' conditions with standard deviations (italics) and total N in square brackets

Pulse Rate	400 ms		500 ms		666 ms		1000 ms	
	paced	unpaced	paced	unpaced	paced	unpaced	paced	unpaced
Beat	89.4	99.2	81.0	116.2	118.0	175.8	218.5	273.2
Alignment to	42.6	43.5	34.5	56.5	48.8	50.1	100.1	104.3
Metronome	[66]	[65]	[72]	[69]	[76]	[72]	[65]	[55]
Beat	85.5	104.6	86.0	117.0	107.8	169.6	172.3	243.3
Alignment to	34.6	43.4	39.2	48.7	43.8	58.3	59.6	80.1
Music	[77]	[71]	[77]	[72]	[79]	[72]	[61]	[48]

To compare unpaced and paced performance in the metronome task 2 x 4 (Task: paced, unpaced metronome task x Rate: 400ms, 500ms, 666ms, 1000ms) ANOVA was carried out taking rate as the dependent variable. The ANOVA showed a main effect of Task, $F(1,32) = 125.8$, $p < .0001$ showing that there was a significant difference between the children's performance as they moved from the 'paced' to the 'unpaced' condition. The main effect of rate also was highly

significant, $F(3,96) = 18.5$, $p < .0001$. The children found the task more difficult as the rates got slower. At 400ms the difference in performance was 13ms, at 500ms – 40ms, at 666 -60ms, and at 1000ms it was 80ms. The interaction between Task and Rate was also highly significant. $F(3,96) = 17.5$, $p < .0001$.

In the beat alignment to music tasks a similar picture emerged. To compare unpaced and paced performance in the with music task a 2 x 4 (Task: paced, unpaced with music task x Rate: 400ms, 500ms, 666ms, 1000ms) ANOVA was carried out taking rate as the dependent variable. The ANOVA showed a main effect of Task, $F(1,30) = 119.4$, $p < .0001$ showing that there was again a significant difference between the children's performance as they moved from the 'paced' to the 'unpaced' condition. The main effect of rate also was highly significant, $F(3,90) = 36.6$, $p < .0001$. The children found this task equally difficult as the rates got slower. At 400ms the difference in performance was 19ms, at 500ms – 31ms, at 666 - 60 ms, and at 1000ms it was 80ms. The interaction between Task and Rate was also highly significant. $F(3,90) = 6.6$ $p < .0001$.

Both analyses show that the children found the tasks in the 'unpaced' condition equally difficult in both the 'with music' and with the metronome stimuli. More children were able to attempt the 'with music' tasks.

When I looked for correlations between the unpaced condition with both metronome and with music I found no correlations with the Phonological measures. For this reason and for the fact that I found it extremely difficult to encourage the young children to carry on playing when the stimuli stopped, the test was not thought to be appropriate for this young age of children. When a similar test was trialled with 10 year-old children in the Thomson dyslexic trials (2008) similar results were found.

(b) Singing to Music

(i) For the measure of Singing in Time (to the Hello song played at different pulse rates – see Table 4.1.4.), a one-way ANOVA was run taking Rate as the repeated factor. Mean beat alignment in ms was the dependent variable, and missing values in the data were replaced by median scores. The

ANOVA showed a main effect of Rate, $F(3,276) = 28.8$, $p < .001$. Post-hoc inspection of the means using Tukey post-hoc tests showed that children were as accurate at singing in time at the rates of 400 ms, 500 ms and 666 ms, but were significantly less accurate at 1000 ms than at all these other rates (p 's $< .001$).

Overall, in contrast to keeping time on the Bongo drums, with their own voices children were not only more accurate at the rates of 400 ms and 500 ms, but were also more accurate at the rate of 666 ms in comparison to the slowest rate (1000 ms).

(ii) The two singing tasks in which the missing rhymes had to be supplied (see Table 4.1.4) also used the child's voice as the dependent measure, hence singing the rhyme on time with the beat in these two tasks (-Music, +Music) was compared using a 2 x 4 (Task: Singing the Rhyme, -Music; Singing the Rhyme, + Music; x Rate: 400 ms, 500 ms, 666 ms, 1000 ms) ANOVA, taking mean beat alignment in ms as the dependent variable. Missing values in the data were again replaced by median scores.

Table 4.1.4. Beat accuracy (mean in ms) by singing task, with median in parentheses and standard deviations and total N in square brackets

Task	400 ms	500 ms	666 ms	1000 ms
Singing in Time	68.3 (59.0) [39.4, 79]	72.9 (68.0) [32.9, 86]	66.1 (55.0) [37.5, 78]	106.9 (104) [52.0, 74]
Singing the Rhyme, - Music	87.9 (77.0) [45.7, 85]	69.1 (60.0) [33.4, 86]	81.6 (74.0) [39.1, 81]	90.7 (69.5) [71.6, 84]
Singing the Rhyme, +Music	98.7 (95.5) [60.3, 84]	59.0 (54.0) [30.6, 85]	70.5 (63.0) [34.4, 85]	102.2 (84.0) [59.4, 85]

The ANOVA showed a significant main effect of Rate, $F(3,276) = 20.4$, $p < .001$. Post-hoc inspection of the means using Tukey post-hoc tests showed that the children were best of all at singing on time with the beat for the 500 ms pulse rate, even compared to the rate of 666 ms, $p < .05$. They were most accurate next at the rate of 666 ms, for which keeping the beat was significantly more accurate than for the slowest rate (1000 ms) and the fastest rate (400 ms,

p 's < .001). Singing the Rhyme at the slowest (1000 ms) and fastest (400 ms) speeds did not differ in accuracy, and children were significantly poorer at keeping time when singing at both of these pulse rates (p 's < .001). The main effect of Task did not reach significance, $F(1,92) = 0.059, p = .80$, but the interaction between Rate and Task was significant, $F(3,276) = 3.9, p < .010$. Post-hoc inspection of the interaction using Newman-Keuls post-hoc tests showed that there were no significant differences between tasks at any rates ($p = 0.2$ at 400ms and 0.1 at the other rates) although there were highly significant differences between tasks at the different rates. The post-hoc tests showed that there were significant differences ($p < .01$) between the performance of the children at the rates of 500ms and their performance at 400ms and 1000ms. The same highly significant differences were found between the performance of the children at 666ms and the fastest and slowest rates,

Although the post-hoc tests showed no significant differences between tasks the scores in Table 4.1.4 give an indication of the variations of accuracy at the different rates. For the most accurate temporal rate (500 ms), children were more accurate at keeping the beat in the +Music condition (59 ms), where they were singing along to rich musical accompaniment, than in the – Music condition (voice alone, 69 ms). For the second most accurate temporal rate (666 ms), there was a difference of 11 milliseconds favouring the + music condition (+Music, 71 ms, -Music, 82 ms)

The -Music condition was more helpful with respect to keeping time at the very slow rate of 1000 ms (91 ms versus 102 ms), and also at the fastest rate of 400 ms (88 ms versus 99 ms). The 500 ms (2 Hz) rate was again the temporal rate for which rhythmic accuracy was highest. This time however there was a benefit from a richer musical experience for both the 500 and 666 ms, as keeping the beat was significantly better at these rates when the children were singing along to music than to a voice alone.

4.2 Study 1 Results from the Rhythmic entrainment in both Drumming and 'Singing in Time' Tasks Compared

If there is an underlying biological trait to entrain to a beat present in young children, a possible hypothesis worth exploration would be that there should be a correlation between the singing in time task and the tasks that tested

accuracy of playing in time tapping along to the Bongo drums. Goswami, (2011) explored this hypothesis and considered that the auditory mechanism within the brain that searches within the Delta and Theta oscillatory networks for beats would find them in both tasks. She states that :-

“as rhythm and meter are more overt in music than in language it might be that remediation based on music and rhythm (ideally multi-modal) such as matching syllable patterning to metrical structure in music (singing), and playing instruments or moving in time with rhythms or rhythmic language (e.g. metrical poetry), will impact phonology and language development, for example via sub-cortical structures such as the cerebellum. “

Although there are differences in the dynamics of the physical nature of the tests, one tapping and the other singing, I worked within the parameters of the ‘temporal sampling theory’ and sought to find relations between temporal accuracy in the rhythmic entrainment and singing tests by computing partial correlations between the beat alignment with music task and the Singing in Time task, taking general cognitive ability (WPPSI) as the covariate (see Table 4.2.1). (See section 6.2. and figure 6.2.2 for further corroborative evidence for the validity of the analysis.)

This analysis was used because correlational analyses carried out by McAuley et al. (2006) and replicated by Corriveau (2009) showed that children with higher nonverbal IQ could synchronize their tapping accurately to a wider range of rates. This finding illustrates the importance of controlling for non-verbal IQ in developmental studies of motor abilities.

I found that the beat alignment to metronome task at 500ms was significantly correlated with I.Q ($r = -.320$, $p = .002$) and there was near significance for the correlation with the metronome task at 666ms ($r = -.187$, $p = .072$). The Singing in Time measure was close to significance when correlated with I.Q. for the rates of 500 ms ($r = -.181$, $p = .083$), and the beat alignment with music task was close to significance when correlated with I.Q. for the 666 ms rate ($r = -.191$, $p = .067$). Both the Singing in Time measure and the beat alignment to music measure used a rich musical accompaniment to support temporal accuracy (drumming or singing). It is theoretically important to

compute relations with all forms rhythmic entrainment, so these correlations are shown in Table 4.2.1.

Inspection of Table 4.2.1 reveals that in this study there were more significant correlations when the rhythmic entrainment task involved a rich musical accompaniment (beat alignment with music correlated with Singing in Time) than when the entrainment task did not involve music (the metronome measures).

There were no correlations at the 400ms rate. The accuracy of playing the Bongo drums in time with the 666 ms rate was significantly correlated with singing in time at 500 ms ($r = .207$, $p = .047$). Playing the drums at 666 and 1000ms rates was significantly correlated with singing in time at 666ms ($r = .299$, $p = .004$, $r = .290$, $p = .005$ respectively). For the pure measure of rhythmic entrainment (drumming in time with the metronome), there was only 1 correlation that was significant (drumming at 666 ms and singing at 500 ms, $r = .215$, $p = .040$)

Table 4.2.1 suggests that more accurate entrainment in drumming to music was significantly related to more accurate rhythmic embodiment in singing, especially for the 500 ms and 666 ms singing rates (2 Hz, 1.5 Hz). Playing the drums at 666 and 1000ms rates when correlated with singing in time at 666ms remained significant after Bonferroni corrections for multiple comparisons (p values $< .004$) were applied.

Table 4.2.1. Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q.

Bongo Drum tasks	Singing in Time, 400 ms	Singing in Time, 500 ms	Singing in Time, 666 ms	Singing in Time, 1000 ms
Metronome 400	0.036	-0.003	0.115	-0.003
Metronome 500	0.178	-0.097	0.200	0.002
Metronome 666	0.061	0.215*	0.196	-0.006
Metronome 1000	0.138	0.060	0.160	-0.087
Music 400	0.165	0.180	0.042	-0.025
Music 500	0.089	0.119	0.163	0.002
Music 666	0.008	0.207*	0.299**	0.085
Music 1000	0.181	0.103	0.290**	0.085

4.3 *Relations between the Music and the Phonological Awareness Tasks*

Possible relations between rhythmic timing and beat alignment and children's performance in the phonological awareness tasks were next explored. Performance in three of the phonological awareness tasks was significantly correlated with I.Q, with the picture syllable task at near significance, hence I.Q. was controlled using partial correlations (oral rhyme standard score and WPPSI, $r = .419$, $p = .000$; picture rhyme and WPPSI, $r = .440$, $p = .000$; oral syllable and WPPSI, $r = .558$, $p = .000$; and picture syllable and WPPSI, $r = .207$, $p = .073$).

Based on the 'temporal sampling theory' we should be able to see a relationship between rhythmic entrainment and syllable-level entrainment in the speech stream. It would be expected that there would be a relationship between temporal accuracy and phonological awareness in both syllable and rhyme linguistic levels. Relations for the rhythmic entrainment tasks (temporal accuracy on the Bongo drums to the metronome and to music) are shown in Table 4.3.1. Relations for the singing tasks (Singing in Time, Singing the Rhyme with and without musical accompaniment) are shown in Table 4.3.2

Inspection of Table 4.3.1 reveals only one significant relationship for the metronome task. Drumming at the 400 ms (2.5 Hz) rate was significantly related to performance in the oral syllable task ($r = -.240$, $p = .027$). There was also a very near significant relationship between the metronome 500ms task and performance in the Oral Syllable task ($r = -.212$, $p = .051$). For the drumming to music task, all temporal rates except the 1000ms (1Hz) rate showed significant correlations with phonological awareness. For the 400ms (2.5Hz) rate the significant correlations were with oral syllable awareness ($r = -.281$, $p = .009$). For the 500ms (2. Hz) rate the significant correlations were with picture rhyme and oral syllable awareness ($r = -.253$, $p = .020$, and $r = -.243$, $p = .025$). For the 666ms (1.5 Hz) rate, significant relationships were with picture rhyme awareness and oral syllable awareness ($r = -.257$, $p = .018$, and $r = -.236$, $p = .030$).

*Table 4.3.1. Pearson's Partial Correlations between Rhythmic Entrainment and Phonological Awareness, controlling for I.Q.
(all Phonological Awareness scores = percentages)*

Bongo Drum tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Metronome 400	-0.020	-0.053	-0.240*	0.057
Metronome 500	-0.066	-0.052	-0.212	0.219
Metronome 666	-0.078	-0.083	-0.070	0.089
Metronome 1000	-0.126	-0.149	0.028	0.128
Music 400	-0.069	-0.172	-0.281**	-0.175
Music 500	-0.070	-0.253*	-0.243*	-0.087
Music 666	-0.113	-0.257*	-0.236*	-0.001
Music 1000	-0.113	-0.106	0.091	0.041

Overall for different measures of rhythmic entrainment (to a metronome versus music), all the rates of greatest pulse salience (400ms, 500 ms and 666ms) showed some significant correlations with oral language processing (phonological awareness of rhymes and syllables). The most consistent relationships between rhythmic entrainment and phonological awareness occurred for drumming to music at 500 ms and 666ms with only one significant relationship with the metronome task at 500ms and the oral syllable task.

Individual differences in the temporal accuracy of entrainment, whilst drumming, by young children in this group of participants do show some significant connections with their phonological awareness.

For the singing measures (Singing in Time, Singing the Rhyme, see Table 4.3.2), there were no significant correlations between phonological awareness and temporal accuracy

Even though singing is a good measure of rhythmic embodiment, temporal accuracy in singing was not strongly related to phonological awareness in this group of participants.

Finally, if rhythmic entrainment is related to phonological awareness, then it should also be related to reading development, which depends in part on phonological awareness. Partial correlations were used to assess relations between the rhythmic entrainment measures using the Bongo drums (metronome task, beat alignment to music) and reading ability, controlling for cognitive ability (WPPSI score).

Table 4.3.2. Pearson's Partial Correlations between Singing Tasks and Phonological Awareness, controlling for I.Q.

(all Phonological Awareness Scores = percentages)

Singing tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Singing in Time, 400	0.040	-0.053	0.106	0.027
Singing in Time, 500	-0.041	-0.122	-0.100	-0.073
Singing in Time, 666	0.106	-0.098	-0.052	0.117
Singing in Time, 1000	0.007	-0.063	0.182	-0.026
Rhyme, -Music 400	-0.045	-0.107	-0.052	-0.135
Rhyme, -Music 500	0.028	-0.124	-0.074	-0.170
Rhyme, -Music 666	-0.098	-0.158	0.025	-0.135
Rhyme, -Music 1000	-0.044	-0.059	0.069	-0.012
Rhyme, +Music 400	-0.157	-0.102	-0.006	-0.113
Rhyme, +Music 500	-0.036	-0.072	-0.022	-0.091
Rhyme, +Music 666	0.089	-0.030	-0.040	0.131
Rhyme, +Music 1000	-0.041	-0.023	-0.012	-0.004

< .05, **p< .01

The children tested within this group of participants had had no formal reading tuition, and had only had a few weeks training on letter sounds and their correlations to the letter symbols. They were therefore tested on their reading ability a year after the original tasks were completed. The results showed a significant time-lagged correlation between rhythmic entrainment to the metronome at the 666 ms rate and reading a year later, $r = -.316$, $p = .004$. The relationship between drumming to music at the 400 ms rate and reading a year later just missed significance, $r = -.215$, $p = .051$. When the Singing in Time to music measure was used there was a significant time-lagged correlation between singing in time at the 500 ms rate and reading performance a year later, $r = -.243$, $p = .027$).

Rhythmic entrainment in the singing tasks is related to the development of reading, but for the 500 ms (2 Hz) pulse rate only. Rhythmic entrainment via drumming is also related to the development of reading, for the rates of 666 ms (drumming to the metronome beat) and 400 ms (drumming to music).

Chapter 5 Results from Study 2

The experimental design for Study 2 was divided into two parts. The experimental tasks from Study 1 were repeated. This was done to see whether the relationships found in the first study would be replicated. The second aim was to see whether rhythmic abilities could be improved by training using a short musical intervention. To explore possible training effects a three-group study was devised. This compared the effect of a musical intervention to a speech-based intervention and incorporated an added control group who simply followed their normal curriculum without any additional support.

This chapter reports the replication data.

The results in this chapter are presented in 3 parts:-

- 5.1. describes the participants and the details of the tasks
- 5.2 describes the results gained from the analysis of the data collected in both the drumming and singing entrainment tasks from Study 2
- 5.3 describes the analysis of the music tasks and their correlation with the psychometric and Phonological Awareness tasks from Study 2

(Any variations in results between the Studies are discussed in the following chapter.)

5.1. Participants and Methodology

5.1.1 Participants

<i>Ofsted and 'On-entry' data for the Replacement School 7 in Study 2</i>				
School 7	Number on roll	Number in Reception	FSP	FSP Comment
	66 (2009)	15	42	Satisfactory
<i>"The proportion of pupils who are identified with learning difficulties and/or disabilities is well above average. Additionally a well above average proportion of pupils have a statement of special educational need. "</i>				

The Study 2 participants came from 99 children in six of the Northumberland First schools used in Study 1. A further school was recruited to replace School 7 that had withdrawn from the study. This school had a combined class of reception and 8 year-one children of lower ability. The year one children were not tested, but took part in the preliminary musical activities in the training programme. The reception classes in each school varied in size from 7 children to 18. Testing commenced in November 2010. (This explains the slight variation in age between Studies I and 2 shown below.)

	Study 1 (2009)	Study 2 (2010)	Full Study
Female	38	43	81
Male	55	56	111
Age in months	59.6 (<i>S.D.</i> 3.4)	57.3(3.5)	58.4(3.7)
Full Study total	93	99	192

5.1.2 Measures

All tests were repeated with the exception of the ‘unpaced’ beat alignment task.

5.1.3 The Preliminary Musical activities and Test Environment

These were all identical to those carried out with Study 1 (see section 3.4.1)

5.1.4. Participant Details are shown in table 5.1.1

Table 5.1.1 Participant details in Study 2

	Mean	(SD)
Chronological age (months)	57.3	(3.5)
Foundation Stage Profile (%)	52.1	(6.4)
Communication, Language & Literacy (FSP subscale %)	43.8	(7.8)
WPPSI (standard score, mean = 100, SD 15)	107.4	(14.4)
Word Recall (standard score, mean = 100, SD 15)	105.0	(13.4)
BAS (standard score, mean= 100, SD 15)	105.9	(13.7)
<i>(concurrently with other post tests)</i>		
Rhyme Oral (standard score)	98.1	(11.8)
“ (% score)	44.1	(21.8)
Rhyme Picture (% correct)	59.1	(31.6)
Syllable Oral (% correct)	62.2	(32.4)
Syllable Picture (% correct)	50.0	(29.2)

5.2 Results for the drumming and singing entrainment tasks in Study 2

Beat Alignment tasks

The rhythmic entrainment data were presented in Table 5.2.1 for the metronome task and the beat alignment to music task, both of which used Bongo drums as the dependent variable. Singing data were presented in Table 5.2.2 (Singing in Time; Singing the Rhyme, -Music; Singing the Rhyme, +Music).

Any responses that were ± 2 SD outside the mean response time for an individual child were first removed from the data (2.7% responses removed in the rhythmic entrainment tests and 4.43% responses removed in the singing tests).

Inspection of the Tables shows once again more children contributed scores in the Singing tasks (Table 5.2.2) than in the rhythmic entrainment drumming tasks (Table 5.2.1). The least number of participants to complete the task was nearly always at 1000ms (1 Hz) rate.

All of the data from Study 2 are consistent with the results found in Study 1. (See Section 6.1 for analysis data.)

Table 5.2.1 Beat accuracy (mean in ms) by rhythmic entrainment drumming task, with median in parentheses and standard deviations and total N in square brackets.

Pulse Rate	400 ms	500 ms	666 ms	1000 ms
Metronome	97.8 (95) [30.8, 82]	99.7 (100) [36.2, 87]	124.6 (126.0) [46.8, 85]	198.9 (186.0) [84.5, 75]
Beat Alignment to Music	85.6 (86.0) [30.3, 90]	86.6 (86.0) [37.9, 86]	110.9 (110) [38.8, 79]	168.4 (169.5) [64.1, 66]

Table 5.2.2 Beat accuracy (mean in ms) by singing task, with median in parentheses and standard deviations and total N in square brackets.

Task	400 ms	500 ms	666 ms	1000 ms
Singing in Time	74.3 (60.0) [39.4, 90]	73.5 (66) [36.9, 92]	78.0 (70) [40.6, 92]	133.1 (120) [63.9, 83]
Singing the Rhyme, - Music	91.7 (79.0) [51.8, 87]	64.8 (55.5) [33.5, 90]	74.6 (66.0) [37.6, 92]	78.9 (71.0) [54.7, 91]
Singing the Rhyme, +Music	98.6 (87.0) [58.9, 95]	53.2 (49.0) [28.3, 90]	75.2 (68.0) [40.6, 92]	102.8 (90.5) [52.1, 92]

(a) Drumming Tasks to metronome and music

As in Study 1 the metronome task and the beat alignment with music task used the Bongo drums. The rhythmic entrainment in the two tasks was compared using a 2 x 4 (Task: Metronome, Music x Rate: 400 ms, 500 ms, 666 ms, 1000 ms) ANOVA. Mean beat alignment in ms was the dependent variable, and missing values in the data were replaced by median scores. The ANOVA showed a significant main effect of Task, $F(1,98) = 48.8$, $p < .001$, because children were significantly more accurate in the music task than in the metronome task overall, and a significant main effect of Rate, $F(3,294) = 189.7$, $p < .001$. The significant main effect of Rate was investigated using Tukey post-hoc tests, and arose because the children were equally accurate at the two faster speeds (400 ms, 500 ms), but then declined significantly in accuracy for the 666 ms rate, and declined significantly again in accuracy for the 1000 ms rate (p 's $< .001$). There was also a significant interaction between Task and Rate, $F(3,294) = 4.46$, $p < .004$. Post-hoc inspection using Newman Keuls post-hoc tests revealed that children were significantly more accurate in the musical task than in the metronome task in entraining to the beat at the 666ms and 1000ms rates (p 's $< .001$). For both the 400ms (2.5 Hz) and 500 ms (2 Hz) rate they were as accurate in keeping the beat with the metronome as with a piece of music ($p = < .05$). For the metronome task, they were equally accurate in keeping the beat at the two faster speeds (400 ms, 500 ms), and were significantly more accurate

at these two speeds than at either 666 ms or 1000 ms ($p's < .001$). For the music task, they were also equally accurate at keeping the beat at 400 ms and at 500 ms, and they were significantly more accurate at these speeds than at either 666 ms or 1000 ms ($p's < .001$).

As in Study 1 the children's rhythmic entrainment was best at 400 ms and 500 ms. At the 1000ms rate they gained most significant benefits in terms of temporal accuracy from the richer musical experience.

(b) Singing to Music

(i) For the measure of Singing in Time (to the Hello song played at different pulse rates), a one-way ANOVA was run taking Rate as the repeated factor. The ANOVA showed a main effect of Rate, $F(3,294) = 44.5$, $p < .001$. Post-hoc inspection of the means using Tukey post-hoc tests showed that children were as accurate at singing in time at the rates of 400 ms, 500 ms and 666 ms, but were significantly less accurate at 1000 ms than at all these other rates ($p's < .001$).

In contrast to keeping time on the Bongo drums, with their own voices children were not only more accurate at the rates of 400 ms and 500 ms, but were also more accurate at the rate of 666 ms in comparison to the slowest rate (1000 ms).

(ii) The two singing tasks in which the missing rhymes had to be supplied also used the child's voice as the dependent measure, hence singing the rhyme on time with the beat in these two tasks (-Music, +Music) was compared using a 2×4 (Task: Singing the Rhyme, -Music; Singing the Rhyme, +Music; x Rate: 400 ms, 500 ms, 666 ms, 1000 ms) ANOVA, taking mean beat alignment in ms as the dependent variable. Missing values in the data were again replaced by median scores. The ANOVA showed a significant main effect of Rate, $F(3, 294) = 28.9$, $p < .001$. This arose because the children were best of all at singing on time with the beat for the 500 ms pulse rate, even compared to the rate of 666 ms, $p < .001$. They were most accurate next at the rate of 666 ms, for which keeping the beat was significantly more accurate than for the slowest rate (1000 ms) and the fastest rate (400 ms, $p's < .001$). Singing the Rhyme at the slowest

(1000 ms) and fastest (400 ms) speeds did not differ in accuracy, and children were significantly poorer at keeping time when singing at both of these pulse rates (p 's < .001). The main effect of Task did not reach significance, $F(1,98) = 3.4$, $p = 0.07$) but the interaction between Rate and Task was highly significant, $F(3,294) = 6.3$, $p < .001$. Post-hoc inspection of the interaction using Newman-Keuls post-hoc tests showed that for the most accurate temporal rate (500 ms), there was no significant difference when the children were keeping the beat in the +Music condition (53 ms). When they were singing along to rich musical accompaniment, compared to the -Music condition (voice alone, 65 ms, $p < .06$). For the second most accurate temporal rate (666 ms), keeping to the beat was equivalent across the two conditions (+Music, 75 ms, -Music, 75 ms, $p = 1.0$). The -Music condition was more helpful with respect to keeping time at the very slow rate of 1000 ms (96 ms versus 103 ms, $p < .001$), and also at the fastest rate of 400 ms (92 ms versus 99 ms, $p < 0.1$).

In this group of participants the 500 ms (2 Hz) rate was again the temporal rate for which rhythmic accuracy was highest whilst the children sang. This time however there was a benefit from a richer musical experience for the most accurate speed (500 ms), as keeping the beat was significantly better at this rate when the children were singing along to music than to a voice alone.

(c) Rhythmic entrainment in both Drumming and 'Singing in Time' Compared

If a general rhythmic embodiment is present in these young children, then the accuracy of singing in time should be correlated with the accuracy of playing the Bongo drums in time. Relations between temporal accuracy in the rhythmic entrainment and singing tests were explored by computing partial correlations between the beat alignment with music task and the Singing in Time task, taking general cognitive ability (WPPSI) as the covariate (see Table 5.2.1). This was done because the Singing in Time measure was significantly correlated with I.Q. for the rates of 400 ms ($r = -.291^{**}$, $p = .004$), and the beat alignment with music task approached significance when correlated with I.Q. for the 500 ms rate ($r = -.183$, $p = .069$). The metronome task was not significantly correlated with I.Q. at any rate. Both the Singing in Time measure

and the beat alignment to music measure used a rich musical accompaniment to support temporal accuracy (drumming or singing). As it is theoretically important to also compute relations with pure rhythmic entrainment (the metronome task), these correlations are also shown in Table 5.2.3.

Table 5.2.3 Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q.

Bongo Drum tasks	Singing in Time, 400 ms	Singing in Time, 500 ms	Singing in Time, 666 ms	Singing in Time, 1000 ms
Metronome 400	-0.055	0.162	0.163	0.202*
Metronome 500	0.085	0.116	0.160	0.133
Metronome 666	0.176	0.157	0.038	0.181
Metronome 1000	0.245*	0.091	0.083	(p= 0.075) 0.216*
Music 400	0.178	0.242*	0.157	0.142
Music 500	0.080	0.344**	0.189	0.114
Music 666	0.106	0.135	(p=0.062) 0.272**	0.107
Music 1000	0.084	-0.002	0.044	0.145

Inspection of Table 5.2.3 reveals that there were more highly significant correlations when the rhythmic entrainment task involved a rich musical accompaniment (beat alignment with music correlated with Singing in Time) than when the entrainment task did not involve music (the metronome measures). The accuracy of playing the Bongo drums with music at both the 400ms and 500 ms rates was significantly correlated with singing in time at the 500 ms rate ($r = .242$, $p = .015$; and $r = .344$, $p = .003$ respectively).

Drumming with Music at the 666 ms rate ($r = .272$, $p = .007$) correlated with singing at 666 ms. There was also a near significant correlation between drumming accuracy at 500ms and Singing in Time at 666 ms ($r = .189$, $p = .062$). For the pure measure of rhythmic entrainment (drumming in time with the metronome), there were significant correlations between Singing in Time at 1000ms and the metronome tasks at 400 and 1000ms ($r = 0.202$, $p = .046$ and $r =$

216, $p = .033$ respectively) and a near significant correlation with the 666ms metronome task ($r = .181$ $p = .075$). This is not surprising since in all tasks the children have found this rate particularly difficult to play or sing along to and it is notable that this rate lies at the slowest point on the region of greatest pulse salience. There was also a significant correlation between Singing in Time at 400ms and the metronome task at 1000ms ($r = .245$, $p = .015$).

Table 5.2.3 suggests that more accurate entrainment in drumming to music was significantly related to more accurate rhythmic embodiment in singing, especially for the 500 ms rate (2 Hz,). This is confirmed by the fact that none of the significant correlations in the metronome tasks would survive Bonferroni corrections for multiple comparisons (p values $> .004$). Only rhythmic entrainment to music at 500 ms and singing at 500 ms; and drumming at 666 ms and singing at 666 ms, remained significant.

5.3 *Relationships between Beat Alignment and Phonological Awareness tasks in Study 2*

I next explored possible relations between rhythmic timing and beat alignment and children's performance in the phonological awareness tasks. Performance in all four of the phonological awareness tasks was significantly correlated with I.Q., hence I.Q. was controlled using partial correlations (oral rhyme standard score and WPPSI, $r = .503$, $p = .000$; picture rhyme and WPPSI, $r = .279$, $p = .007$; oral syllable and WPPSI, $r = .478$, $p = .000$; and picture syllable and WPPSI, $r = .319$, $p = .002$). Given the hypothesised relationship between rhythmic entrainment and syllable-level entrainment to the speech stream within the 'temporal sampling theory' (Goswami 2011) I expected to find relations between temporal accuracy and phonological awareness in both syllable and rhyme linguistic levels, but within this group of participants relatively few correlations emerged, especially in the entrainment to drumming tasks. Relations for the rhythmic entrainment tasks (temporal accuracy on the Bongo drums to the metronome and to music) are shown in Table 5.3.1. Relations for the singing tasks (Singing in Time, Singing the Rhyme with and without musical accompaniment) are shown in Table 5.3.2.

Table 5.3.1 Pearson's Partial Correlations between Rhythmic Entrainment and Phonological Awareness, controlling for I.Q.

(all Phonological Awareness Scores = percentages)

Bongo Drum tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Metronome 400	-0.170	-0.183	-0.067	0.125
Metronome 500	-0.008	-0.104	-0.074	-0.098
Metronome 666	-0.021	-0.042	-0.044	-0.024
Metronome 1000	-0.089	0.063	0.200 (p=0.055)	-0.038
Music 400	-0.116	-0.097	0.106	-0.059
Music 500	-0.263*	-0.170	-0.092	-0.156
Music 666	-0.125	-0.155	-0.058	-0.107
Music 1000	-0.024	-0.082	0.107	0.101

*p< .05, **p< .01.

i) Correlations between Drumming Tasks and Phonological Awareness Tasks

Inspection of Table 5.3.1 reveals only one near significant relationship for the metronome task. Drumming at the 1000 ms (1 Hz) rate was at near significance when related to performance in the oral syllable task ($r = -.200$, $p = .055$). For the drumming to music task only the 500 ms (2.Hz) rate showed a significant correlations with the Oral Rhyme phonological awareness task ($r = -.263$, $p = 0.012$).

Individual differences in the temporal accuracy of entrainment by young children show a significant correlation with the phonological awareness Oral rhyme task and drumming to music at the 500ms (2.Hz) rate.

ii) Correlations between Singing Tasks and Phonological Awareness Tasks

Table 5.3.2 Pearson's Partial Correlations between Singing Tasks and Phonological Awareness, controlling for I.Q.

(all Phonological Awareness scores = percentages)

Voice tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Singing in Time, 400	-0.173	-0.206*	-0.144	-0.182
Singing in Time, 500	-0.105	-0.046	-0.137	-0.223*
Singing in Time, 666	-0.003	-0.127	-0.207*	-0.084
Singing in Time, 1000	0.047	0.042	0.035	0.055
Rhyme, -Music 400	-0.224*	-0.123	-0.135	-0.040
Rhyme, -Music 500	0.029	-0.113	-0.129	-0.043
Rhyme, -Music 666	-0.091	-0.166	0.005	-0.014
Rhyme, -Music 1000	-0.170	-0.118	-0.211*	-0.078
Rhyme, +Music 400	-0.127	-0.245*	-0.077	-0.247*
Rhyme, +Music 500	-0.063	-0.046	-0.250*	-0.041
Rhyme, +Music 666	-0.015	-0.090	-0.029	0.029
Rhyme, +Music 1000	-0.245*	-0.082	-0.188	-0.091

* $p < .05$, ** $p < .01$

For the singing measures (Singing in Time, Singing the Rhyme, see Table 5.3.2), there were nine significant correlations between phonological awareness and temporal accuracy. For the Singing in Time measure, the 400 ms rate was correlated significantly with picture rhyme awareness ($r = -.206$, $p = .047$). For the 500ms rate there were significant correlations with the picture syllable task ($r = -.223$, $p = .031$). For the 666ms rate there was a significant correlation with the oral syllable task ($r = -.207$, $p = .046$). For the Singing the Rhyme measure, the 400 ms rate in the -Music task was significantly correlated with oral rhyme ($r = -.224$, $p = .034$). For the 1000ms rate there was also a significant correlation between the – Music task and oral syllable task ($r = -.211$, $p = .042$). For the +Music task when the children sang with an accompaniment there were significant correlations between the 400ms rate and both picture rhyme and picture syllable tasks ($r = -.245$, $p = .018$ and $r = -.247$, $p = .016$ respectively). At the 500ms rate there was a significant correlation with the oral syllable task ($r =$

-250, $p = .020$). At the 1000ms rate there was a significant correlation with + Music and Oral Syllable ($r = -.245$, $p = .020$).

Individual differences in the temporal accuracy of entrainment by young children do show some significant correlations with the phonological awareness tasks at all rates, particularly at the 400ms rate. However none of the significant correlations could survive Bonferroni corrections.

Chapter 6 Study Comparisons

In this chapter I compare the results in both Studies to see whether the results were comparable, and whether the increased number of participants (n192) gave more robust evidence to support the various hypotheses.

The chapter is divided into four sections:-

- 6.1 Compares beat alignment tasks in Studies 1 and 2
- 6.2 Compares the results of the correlations between the entrainment tasks in Studies 1 and 2
- 6.3 Compares the Studies in the Psychometric tests
- 6.4 Compares the results of the correlations in the Psychometric tests and their relationship with the entrainment tasks in Studies 1 and 2.

The results in Study 2 in general closely match those found in Study 1 with a small number of differences.

To test whether these differences were significant a series of repeated measures ANOVAs were taken to compare the results from both studies.

6.1 *Beat alignment - Studies 1 and 2 Tasks Compared*

(a) Study comparisons in the Drumming tasks

(i) Drumming to metronome tasks

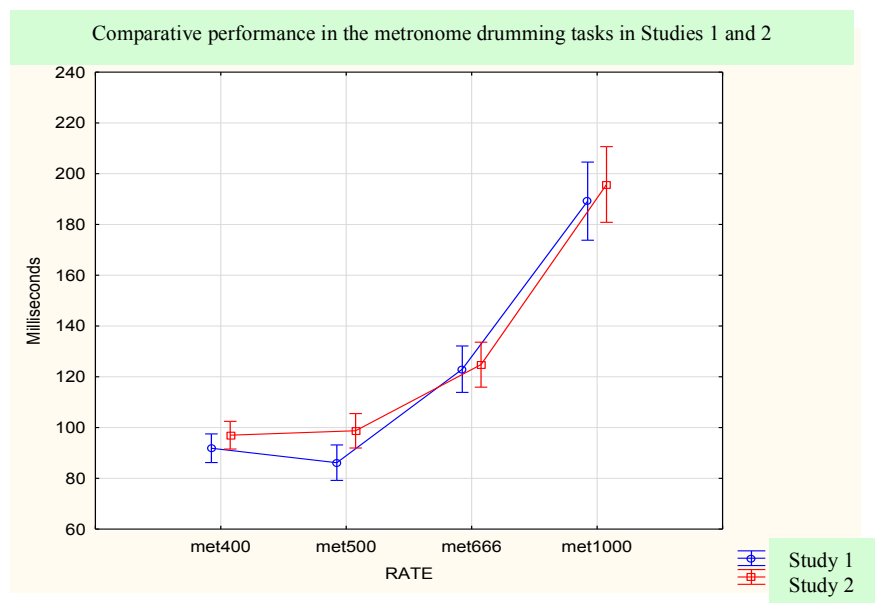
Rhythmic entrainment in the metronome task from both studies was compared using a 2 X 4 (Study: 1 & 2) x metronome drumming rate: 400ms, 500ms, 666ms and 1000ms) ANOVA. Mean beat alignment in ms was the dependent variable. The ANOVA showed no significant main effect of Study ($F(1,190) = 2.4, p < 0.13$) suggesting that the children's performance was consistent in both studies. There was as expected a significant main effect of rate ($F(3,570) = 204.3, p = 0.0001$) because in both studies we see the differences in performance of the children at the different pulse rates,

particularly as they move from 666ms to 1000ms. There was no significant interaction between Study and Rate ($F(3,570) = .475, p < .70$).

Overall across all rates the repeated measures ANOVA showed that the studies were well matched in the drumming to metronome tasks. Figure 6.1.1 gives a graphic representation of how closely the two studies of 5 year- olds were performing.

<p><i>Table 6.1.1</i> <i>Drumming to Metronome Tasks Study Comparisons</i> <i>Scores given show the deviations from absolute synchronisation.</i></p>				
	400ms	500ms	666ms	1000ms
Study 1	91.5	85.4	122.6	189.7
Study 2	97.8	99.7	124.6	198.9

Figure 6.1.1
Studies 1 and 2 compared in
the Metronome drumming
tasks



ii) Drumming to Music Tasks

Rhythmic entrainment in both studies of the drumming to music task was compared using a 2 X 4 (Study: 1 & 2 x metronome drumming rate: 400ms, 500ms, 666ms and 1000ms) ANOVA. Mean beat alignment in ms was the dependent variable. The ANOVA showed no significant main effect of study

($F(1,190) = 1.5$, $p < 0.22$) suggesting once again that the children's performance was consistent in both studies, irrespective of stimuli. There was once again a significant main effect of rate ($F(3,570) = 162.9$, $p = 0.001$) because in both studies we see the differences in performance of the children at the different pulse rates, particularly as they move from 666ms to 1000ms. There was for this task a significant interaction between Study and Rate ($F(3,570) = 5.2$, $p < .001$). Figure 6.1.2 gives a graphic representation of how closely the two studies of 5 year- olds were performing. Newman-Keuls post hoc tests showed that there was a significant difference between studies only at 1000ms ($p = .001$), but at the other rates there were no significant differences (400ms; $p = 0.81$; 500ms; $p = 0.20$; 666ms; $p = 0.21$).

*Figure 6.1.2
Samples 1 and 2 compared in
the drumming to music tasks*

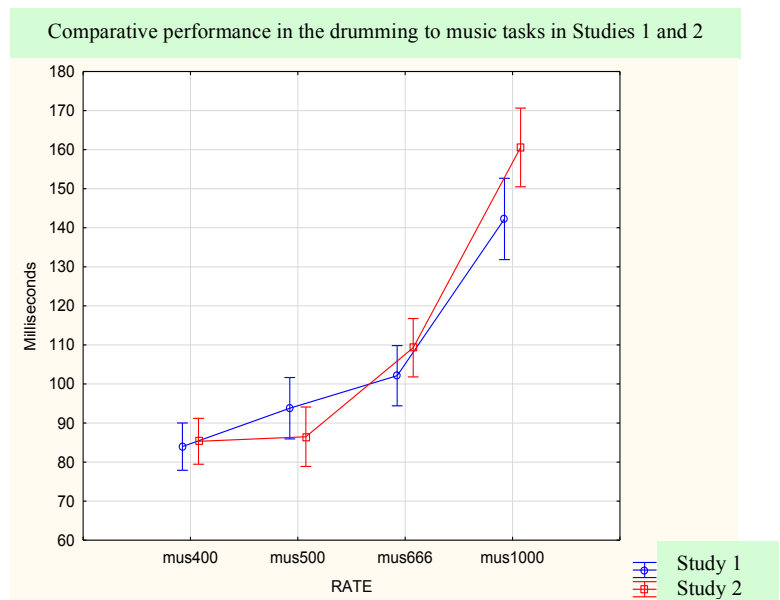


Table 6.1.2

Drumming to Music Tasks Study Comparisons

Scores given show the deviations from absolute synchronisation.

	400ms	500ms	666ms	1000ms
Study 1	84.1	94.3	101.7	140.5
Study 2	85.6	86.6	110.9	168.4

Overall across all rates, except at 1000ms the repeated measures ANOVA showed that the studies were well matched in the drumming to music tasks (see Table 6.1.2.). Figure 6.1.2 gives a graphic representation of how closely the two studies of 5 year- olds were performing.

(b) Study Comparison in the Singing Tasks

In the singing tasks there were also small differences in the studies performances but the overall trends were consistent.

(i) Singing in Time Tasks

Rhythmic synchronisation in both studies for the singing in time to music task were compared using a 2 x 4 (Study: 1 & 2 x singing : 400ms, 500ms, 666ms and 1000ms) ANOVA. Mean beat alignment in ms was the dependent variable. The ANOVA showed a significant main effect of Study ($F(1,190) = 8.2, p < 0.005$) and a highly significant main effect of rate ($F(3,570) = 71.7, p < .0001$) because in both studies we see that there were differences in performance of the children at the different pulse rates.

There was a significant interaction between Study and Rate ($F(3,570) = 2.7, p < .05$). Figure 6.1.3 gives a graphic representation of how closely the two studies were matched in rate but also that there were differences in the children's performances between studies.

Even though the children's performance at the 400, 500 and 666 ms rates were consistent with only small variations in their accuracy from synchronisation with the beat, their performances changed significantly as they attempted the singing in time at the 1000ms rate.

This was confirmed in the Newman-Keuls test, where there was a significant difference between the studies at the 1000ms rate ($p < .0001$). (See also Table 6.1.3)

*Figure 6.1.3
Studies 1 and 2
compared Singing in
Time tasks*

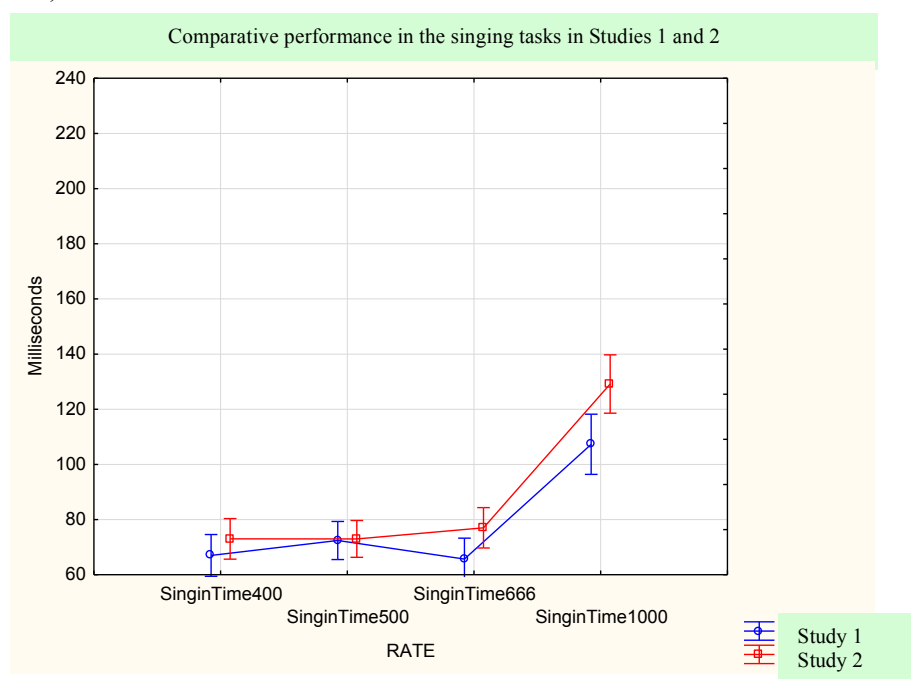


Table 6.1.3

Singing in Time Study Comparisons

Scores given show the deviations from absolute synchronisation.

	400ms	500ms	666ms	1000ms
Study 1	68.3	72.9	66.1	106.9
Study 2	74.3	73.5	78	133

(ii) Singing the Rhyme Tasks-Music

Performance in the Rhyme Tasks without music measures were compared using a 2x4 (Study: 1 & 2) x rate (singing the rhyme without music): 400ms, 500ms, 666ms and 1000ms) ANOVA. Mean beat alignment in ms was the dependent variable. The ANOVA showed no significant main effect of Study ($F(1,190) = 1.34, p < .0.25$). It did show a significant main effect of rate ($F(3,570) = 9.8, p < .0001$ because in both studies the children could better entrain to some rates than others.

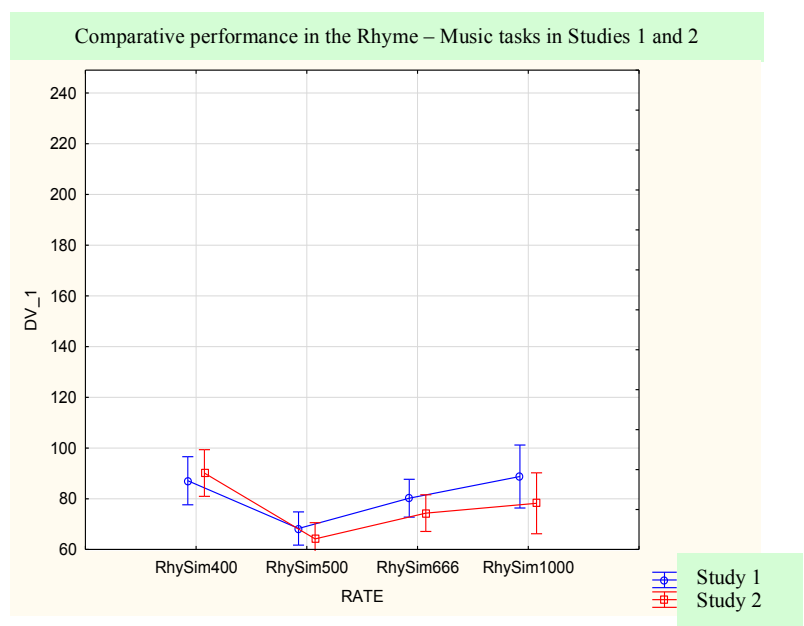
The children performed most accurately at the 500 ms rate in both studies in the singing the rhyme task – music.

Surprisingly the 400ms rate was more inaccurate than in the drumming and Singing in Time entrainment tasks. There was no significant interaction between Study and Rate: $F(3.570) = 0.84, p < .47$.

Figure 6.1.4

Phase 1 and 2 studies

Singing the Rhyme - Music Tasks



<p><i>Table 6.1.4</i></p> <p><i>Singing the Rhyme – Music Study Comparisons</i></p> <p><i>Scores given show the deviations from absolute synchronisation</i></p>				
	400ms	500ms	666 ms	1000ms
Study 1	87.9	69.1	81.6	90.7
Study 2	91.7	64.8	74.6	78.9

Graphic representations are shown in Figure 6.1.4. and synchronisation scores in Table 6.1.4.

(iii) Singing the Rhyme Tasks+Music

Performance in the Rhyme Tasks with music measures were compared using a 2x4 (Study: 1 & 2) x rate (singing the rhyme+ music): 400ms, 500ms, 666ms and 1000ms) ANOVA. Mean beat alignment in ms was the dependent variable. The ANOVA did not show a significant main effect of study ($F(1,190) = 0.001$, $p < .975$). The groups were very evenly matched. It did show a significant main effect of rate ($F(3,570) = 49.2$, $p < .0001$) because in both studies the children could better entrain to some rates than others.

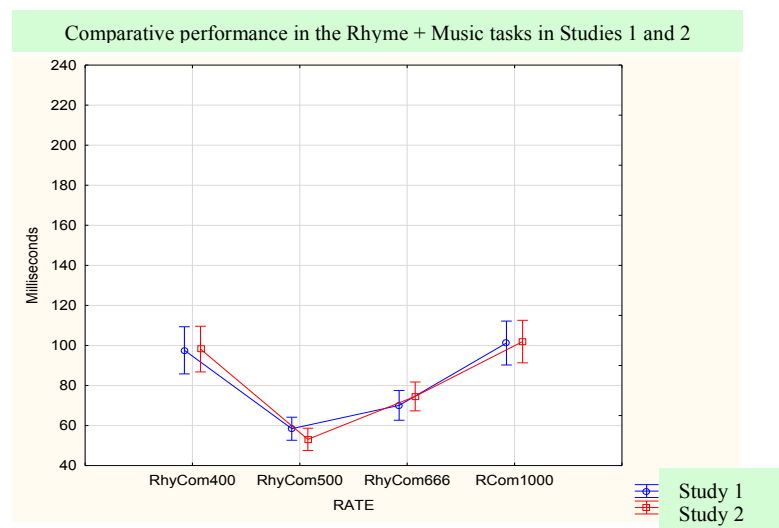
The children performed most accurately at the 500 ms rate in both studies in the singing the rhyme task with music.

Once again the 400ms rate was more inaccurate than in the drumming and Singing in Time tasks. There was no significant interaction between Study and Rate: $F(3,570) = .43$, $p < .74$.

Figure 6.1.5 gives a graphic representation of the study differences and Table 6.1.4 shows the scores.

Figure 6.1.5
Phase 1 and 2 studies

Singing the Rhyme + Music Tasks



<p><i>Table 6.1.5</i></p> <p><i>Singing the Rhyme + Music Study Comparisons</i></p> <p><i>Scores given show the deviations from absolute synchronisation.</i></p>				
	400ms	500ms	666ms	1000ms
Study 1	98.7	59.0	70.5	102.2
Study 2	98.6	53.2	75.2	102.8

A further Repeated Measures (Study: 1 & 2 x Task: Music + and – Music x rate: 400ms, 500ms, 666ms and 1000ms) ANOVA was computed to analyse the impact of both rhyme tasks (With and without Music) within both studies. It showed no main effect of Study ($F(1,190) = 2.1, p < .153$). There was a highly significant main effect of Rate ($F(3,570) = 48.2, p < .0001$). There was no significant interaction of Study and Rate ($F(3,570) = 0.733, p < .53$). ($F(1,190) = 0.001, p < .975$).

In all of these entrainment tasks, both drumming and singing the two studies show considerable similarity. The graphic representations in particular show that despite some small differences, which one would expect in any groups of young children, the major trends across studies were consistent.

In the drumming tasks the children performed more inaccurately at the slower rates (666ms and 1000ms rates) and became increasingly inaccurate at the slowest rate of 1000ms.

In both the Rhyme Tasks with and without music the children favoured the 500ms rate. They found both the fastest rate (400ms) and the slowest rate (1000ms) most difficult to fit their rhyming words to the exact musical beat.

6.2 Rhythmic entrainment in both Drumming and Singing in Time

Studies 1 and 2 Tasks Compared

Table 6.2.1 shows that there were many differences in performance between studies. The only consistent correlation was for drumming with music and Singing in Time at 666ms.

Table 6.2.1 Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q – comparing Study 1 and 2 data.

Bongo Drum tasks	Singing in Time, 400 ms	Singing in Time, 500 ms	Singing in Time, 666 ms	Singing in Time, 1000 ms
	Study 1	Study 2	Study 1	Study 2
Met 400				
Met 500				
Met 666		0.215*		
Met 1000	0.245*			0.216*
Mus 400		0.242*		
Mus 500		0.344**		
Mus 666		0.207*	0.299**	0.272**
Mus 1000			0.290**	

The table however confirms that for these combined correlations there were more significant correlations that could stand up to Bonferroni corrections for multiple comparisons (those scores with **) between the tapping to music and singing in time. This could be expected as the Singing in Time Tasks are with musical accompaniment. There are more significant correlations at the rates of 500 and 666ms. This compares exactly with the Singing the Rhyme tasks.

Because there seemed to be unexpected differences between the two studies it was appropriate to look to see whether these inconsistencies were in evidence when looking at the full study (Table 6.2.2). However the results confirm the general trend seen in both Studies 1 and 2, with far more significant correlations in evidence between the Singing in Time Tasks and the Drumming to Music Tasks.

The correlations in the Full Study of 192 children show a stronger preference between Singing in Time at 500ms with highly significant correlations at 400ms and 500ms drumming to music tasks.

In the full study we do see that Singing in Time at 400ms and Drumming with the metronome at 1000ms, and also Singing in Time at 666ms with the metronome at 500ms will stand Bonferroni comparisons, which is unlike the correlations found in either Studies 1 or 2.

Table 6.2.2 Pearsons Partial Correlations between Rhythmic Entrainment and Singing, controlling for I.Q – in the combined studies (Full Study)

Bongo Drum tasks	Singing in Time, 400 ms Full Study	Singing in Time, 500 ms Full Study	Singing in Time, 666 ms Full Study	Singing in Time, 1000 ms Full Study
Met 400			.151* (p=0.037)	
Met 500			.198** (p=0.006)	
Met 666		.185* (p=0.006)		
Met 1000	.199** (p=0.006)			
Mus 400	.176* (p=0.015)	.122** (p=0.003)		
Mus 500		.226** (p=0.002)	.160* (p=0.027)	
Mus 666		.172* (p=0.017)	.293** (p=0.001)	
Mus 1000			.171* (p=0.018)	

Before I compare the results between studies in the correlations between beat alignments and the psychometric measures it is first necessary to compare the results of the children's performances in the psychometric tests.

6.3 Study Comparisons in the Psychometric Tests

6.3.1 Psychometric Measures compared in Studies 1 and 2

Performances in the Psychometric measures were compared using a 2 x 5 (Study: 1 & 2) x Psychometric tasks: (CLL, FSP, WPPSI, Word Recall and BAS) ANOVA with repeated measures of task. The Psychometric tasks were the dependent variable. The ANOVA showed that there was no significant main effect of Study ($F(1,180) = 0.17, p < .68$). There was a significant main effect of task ($F(4,720) = 2158.5, p < .0001$). The Interaction Task*Study was also highly significant ($F(4,720) = 17.19, p = .0001$). A graphic representation is shown in figure 6.3.1.

Figure 6.3.1
Comparison of
Psychometric measures in
Studies 1 and 2

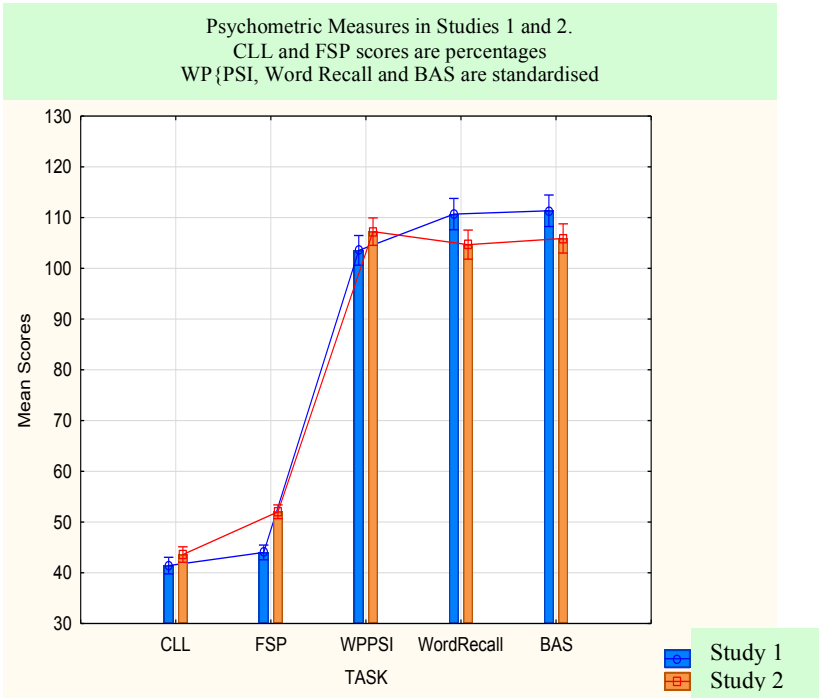


Table 6.3.1

Psychometric Measures Comparisons in Studies 1 and 2

	CLL	FSP	WPPSI	Word Recall	BAS
Study 1	41.4	44.0	103.9	110.9	111.4
Study 2	43.8	52.1	107.4	105.0	105.9

Newman Keuls post-hoc tests confirmed that there were significant differences between the tasks for the two studies:- FSP – $p = .0001$, Word Recall – $p < .004$, and BAS – $p = .01$. The C.L.L and WPPSI tests showed no significant differences $p < 0.22$ and $p < 0.15$. respectively.

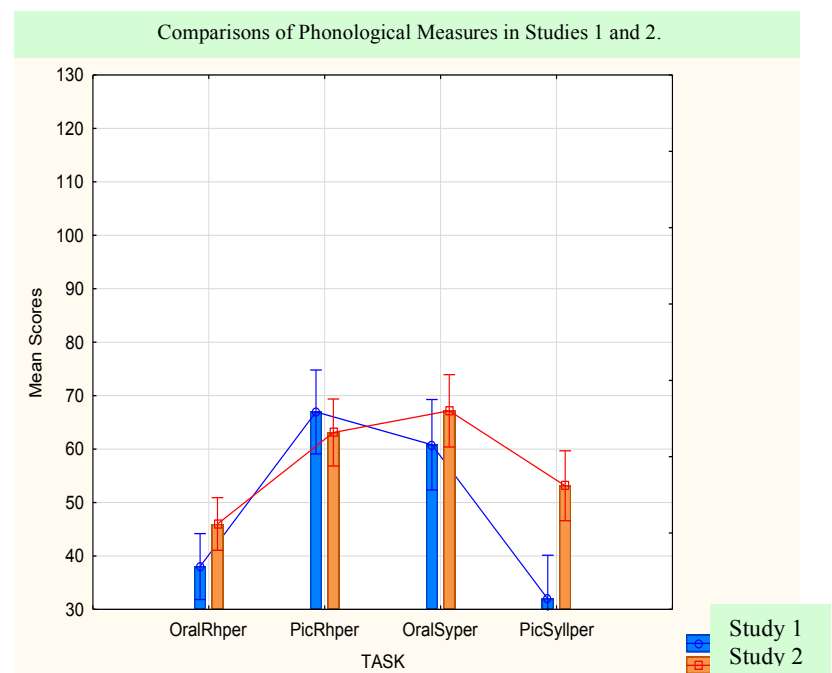
The difference in scores in the BAS reading test could be ascribed to the fact that the children in Study 1 took this test one year after completion of the other tasks.

6.3.2 Phonological Awareness Measures compared in Studies 1 and 2

Performance in the Phonological Awareness measures were compared using a 2x4 (Study: 1 & 2 x Phonological Awareness Tasks: (Oral and Picture Rhyme, Oral and Picture Syllable) ANOVA with repeated measures of task. The P.A measures were the dependent variable. All scores were adjusted to percentages. The ANOVA showed a significant main effect of Study ($F(1.34) = 4.3$, $p < .04$). There was also a significant main effect of task ($F(3.402) = 47.8$, $p < .0001$). In the interaction between Study*Task there was a highly significant effect ($F(3.402) = 7.7$, $p < .0001$).

Newman-Keuls post-hoc comparison tests showed a significant difference between the studies in the picture syllable test :- $p < .0001$. The other tests showed no significant differences between studies. (See table 6.3.2. for scores). A graphic representation is shown in figure 6.3.2

*Figure 6.3.2
Comparison of
Phonological Awareness
Measures in Studies 1 and 2*



*Table 6.3.2**P.A.Measures Comparisons in Studies 1 and 2*

	Oral Rhyme %	Picture Rhyme %	Oral Syllable %	Picture Syllable %
Study 1	34.2	59.6	51.6	30.2
Study 2	44.1	59.1	62.2	50.0

I can only speculate that the teaching of letter sounds had become more rigorous between the two years, and very little attention was given to dividing a word into its syllable components' hence the great change between scores between studies.

6.4 Relationships between Beat Alignment and Phonological Awareness tasks. Studies 1 and 2 Tasks Compared

(i) Drumming Tasks

The comparisons between the two studies in the drumming tasks do show some differences. Table 6.4.1 shows that in Study 1 there were 4 correlations, all between drumming and the Oral Syllable phonological awareness task, but in Study 2 there was only one significant correlation between the Oral Rhyme task and the drumming to music task at 500ms. In Study 2 the correlation between the Oral Rhyme Task and the drumming to Music at 400ms was highly significant and could survive a Bonferroni multiple comparison correction.

Table 6.4.1 Pearson's Partial Correlations between Rhythmic Entrainment in the drumming tasks and Phonological Awareness, controlling for I.Q comparing Studies 1 and 2

(all Phonological Awareness Scores = percentages)

Bongo Drum tasks	Oral Rhyme		Picture Rhyme		Oral Syllable		Picture Syllable	
	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2
Met 400					-0.24*			
Met 500								
Met 666								
Met 1000						0.2 (p=0.06)		
Mus 400					-0.28**			
Mus 500		-0.26*			-0.24*			
Mus 666					-0.27*			
Mus 1000								

Although these correlations do show some relationships between the drumming tasks and phonological awareness the differences between the studies was unexpected since I only found comparable results between the two studies in the Oral Syllable test. Table 6.4.2 show the correlations in the full study.

Table 6.4.2 Pearson's Partial Correlations between Rhythmic Entrainment in the Drumming Tasks and Phonological Awareness, controlling for I.Q in the Full Study

Bongo Drum tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
	Full Study	Full Study	Full Study	Full Study
Met 400			.149* (p=0.045)	
Met 500				
Met 666				
Met 1000				
Mus 400				
Mus 500	.184* (p = 0.02)	.199** (p=0.008)	.162* (p=0.030)	
Mus 666		.210** (p=0.005)	-.136 (p = .07)	
Mus 1000				

In Table 6.4.2 one can now see that in the full study more correlations emerge. There are significant relationships between the drumming tasks with all Phonological Tasks except the Picture Syllable task. However there was a near significant correlation between the Drumming Task at 500ms and the Picture Syllable Task ($p = .07$).

Significantly all but one of the correlations are with the drumming to music tasks. Only the correlations between the Picture Rhyme tasks and Drumming to Music at 500 and 666ms could survive Bonferroni corrections.

ii) Singing Tasks

If the ‘temporal sampling theory’ (Goswami 2011) is correct and singing is a good measure of rhythmic embodiment then temporal accuracy whilst singing should be related to phonological awareness. In Study 1 we found no correlations but in Study 2 more relationships emerged, although none were strong enough to survive Bonferroni corrections (Table 6.4.3).

Table 6.4.3 Pearson’s Partial Correlations between Rhythmic Entrainment in the Singing Tasks and Phonological Awareness, controlling for I.Q. in Studies 1 and 2

Voice tasks	Oral Rhyme		Picture Rhyme		Oral Syllable		Picture Syllable	
	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2
Singing In Time 400ms				-0.21*				
SIT 500ms								
SIT 666ms						-0.207*		
SIT 1000ms								-0.223*
Rhyme Music 400	-	-0.224*						
R-M 500								
R-M 666								
R-M 1000						-0.211*		
Rhyme Music 400	+			-0.245*				-0.247*
R+M 500						-0.250*		
R+M 666								
R+M 1000		-0.245*						

When one combines the scores from both Studies one can perhaps see a more accurate picture of the analysis. The results are shown in Table 6.4.4. It is interesting to note that for these correlations the significant scores are in both Picture Rhyme and Syllable tasks. This task in particular shows that the adapted picture Phonological Awareness tasks are especially useful with this age of young children, and give positive grounds for their inclusion in the testing protocol.

Table 6.4.4 Pearson's Partial Correlations between Rhythmic Entrainment in the Singing Tasks and Phonological Awareness, controlling for I.Q in the Full Study.

Voice tasks	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Singing In Time	Full Study	Full Study	Full Study	Full Study
SIT 400ms				
SIT 500ms				
SIT 666ms				
SIT 1000ms				
Rhyme - Music				
R-M 400				
R-M 500				
R-M 666		0.147* (p=0.05)		
R-M 1000				
Rhyme + Music				
R+M 400		0.179* (p=0.017)		-0.184* (p=0.16)
R+M 500				
R+M 666				
R+M 1000				

Finally, if rhythmic entrainment is related to phonological awareness, then it should also be related to reading development, which depends in part on phonological awareness. Partial correlations were used to assess relations between the rhythmic entrainment measures using the Bongo drums (metronome task, beat alignment to music) and reading ability, controlling for cognitive ability (WPPSI score). In Study 2 there were no significant

relationships for the cross-sectional correlations. The children had received no formal reading tuition at the time of testing.

The Study 1 children were given the BAS test a year after they had been tested in other tasks. In Study 1 I found a highly significant relationship between the Drumming to Metronome task at 666ms and the Reading Test. There was a near significant relationship between the Drumming to Music at 400ms.

Table 6.4.5 Pearson's Partial Correlations between Rhythmic Entrainment and the BAS word reading test controlling for I.Q in the Full Study.

Bongo Drum tasks	BAS Study1	Study 2	Full Study
Met 400			
Met 500			
Met 666			-.158* (p= 0.034)
Met 1000			
Mus 400			
Mus 500			
Mus 666			
Mus 1000			
Singing In time			
400			
500			
666			
1000			
Rhyme - Music			
400			
500			
666			
1000			
Rhyme + Music			
400			
500			
666			
1000			

Of interest is that in the Singing tasks a near reverse result was found. There were no significant results in the drumming tasks, but several in the

Singing Tasks. In the Singing in Time task (the only singing measure that was based on temporal accuracy across several beats) I found significant correlations at both the 400 and 666ms rates respectively. I also found a significant correlation in the singing with music task at the 500ms rate.

Although some further correlations were found in the full study, they cannot be viewed as significant in the overall context, because the children from both studies were different in age and experience.

Chapter 7 A circular statistical analysis of the entrainment to drumming tasks in the full study

In the final section of Chapter 6 when relationships were analysed between the entrainment, psychometric and phonological awareness tasks it is possible to see that by looking at the full study analysis a new perspective could be gained on the children's performance because the study size was enlarged. In the drumming entrainment tasks there was little change between the studies, and yet by reviewing the data using a different statistical model one can add weight to the gathered data. The model chosen for verification of the validity of the previous analyses was one that used 'circular statistical analysis' for the reasons outlined in the Kirschner and Tomasello paper of 2009.³⁵

7.1. Circular Statistics

In Chapter 2, Figure 2.3.2, I gave an example of a circular statistical representation of entrainment between two players of Indian music (Clayton, 2012). This statistical method gives a representation of the accuracy of synchronisation when, in this case, two people play together, even if the beat is not isochronous. Both players were able to perceive a shared beat rate, and even though there were inconsistencies in their ability to keep to this beat, they still could play together because the degree of error was within very few milliseconds. Tomasello and colleagues (2005) supposed that humans have a

³⁵ *"The standard method to assess the degree of synchronization during tapping experiments is to align the stimulus and response sequences on a linear time scale, take the relative deviation or asynchrony of each response tap from the corresponding metronome click, and finally calculate the mean and variance of all asynchronies per trial. Because it was not straightforward to associate the children's taps with the stimulus beats on a one-to-one basis as is required in linear statistics, we chose circular statistics as the appropriate method to calculate mean and variance of the asynchronies" Kirschner and Tomasello (2009)*

species-unique motivation to move in synchrony with each other. In their research with young children they found that a 4.5 year-old child has an ability to synchronise with another player nearly as accurately as an adult – eg within 10 to 100 milliseconds of the beat at a rate of 600ms (2009). They also found that the speed at which the children tapped was also critical for improved synchronisation. Their trials were tested at IOI's of 400 and 600ms. At the slower speed the children anticipated the beat and at the quicker speed they delayed their responses. This is consistent with the adult literature (Large and Jones, 1999; Rep 2005).

(See Figure 3.2.7 for the Audacity representation of an anticipated tapping response.)

A circular statistical analysis calculates a mean or median score from the wide variations of asynchrony from a series of Inter Stimulus Intervals (ISI). (Fisher, 1993; Mardia & Jupp, 2000; Zar, 1999 and Large and Palmer 2002). The series of a group or ISI's is termed a 'phase', and in this study all of the phases consisted of 16 beats. If the children tap in total synchronisation, they are 'in phase', and if there are errors they are 'out of phase'.

To analyse the children's synchronisation using circular statistics, ideally you would create an environment where you can gain very clear signals from the children's recording. This is best done in laboratory settings using a mixer desk that can separate the master and children's recording (Kirschner and Tomasello 2009). It is less easy to gain clear data from recordings made in a wide variety of changing classroom settings where set-up time is extremely limited and space for complicated and well controlled microphone positions is nearly impossible

Table 7.1.1 showing the change of score when the mean score is calculated from the data taking into account whether the beat is anticipated or delayed (+ and –) Scores are calculated from a trial of 16 beats.

Beats	Gross error from point of synchronization in ms	Error showing anticipation or delay from the point of synchronisation
1	8	-8 - = anticipation
2	56	-56
3	49	-49
4	38	-38
5	1	+1 + = delay
6	24	-24
7	14	+14
8	32	+32
9	8	+8
10	16	-16
11	33	-33
12	75	-75
13	24	+24
14	30	-30
15	38	-38
16	32	-32
Mean	30	-20

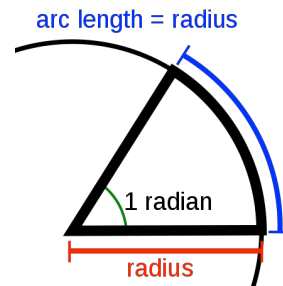
(On several occasions in the school settings used in this research it was necessary to change rooms many times during a session due to prior or unexpected requirements by the school.³⁶). However conversion of the data from linear to circular is possible. In Table 7.1.1 the original data from a child's performance in a given drumming task is shown. In the first row the gross error is given, irrespective of whether the child anticipates or delays their response. This was the method employed to find the error scores, which could be used and correlated with the psychometric, and phonological measures reported in the Results sections above.

After re-analysing the data one can convert the children's responses showing both anticipatory or delayed scores in milliseconds. The final mean scores in Table 7.1.1 show the difference in error scores between the two calculations. When one accounts for the anticipation and delay we see that

³⁶ The schools in this research are very small, and I often had to use the headteacher's study to record since this was the only available quiet space. However any unexpected change in the school routine would mean I couldn't use the room. A staff room was often used, and at every break-time the room had to be tidied of equipment from the desks to allow for coffee and staff conversation.

the final mean score is less in the second calculation. This trend is usually found in circular statistical analyses, in comparison to linear analyses. After re-configuring the data from the original scores into scores showing whether the children anticipated or delayed their responses the new data can be used in a circular statistical analysis.

Circular statistics then transforms each inter-stimulus interval (ISI) into a unit circle, with the stimulus aligned at 0 radians. The data are converted from the linear beat alignment response time scores into radii or radians to give a new score that can be represented on the circumference of a circle. This is done by converting the positive (delay) or negative (anticipating the beat) scores by the length of each beat and multiplying it by 360.



$$(100 \div 400 \times 360 = 90)$$

For example:-

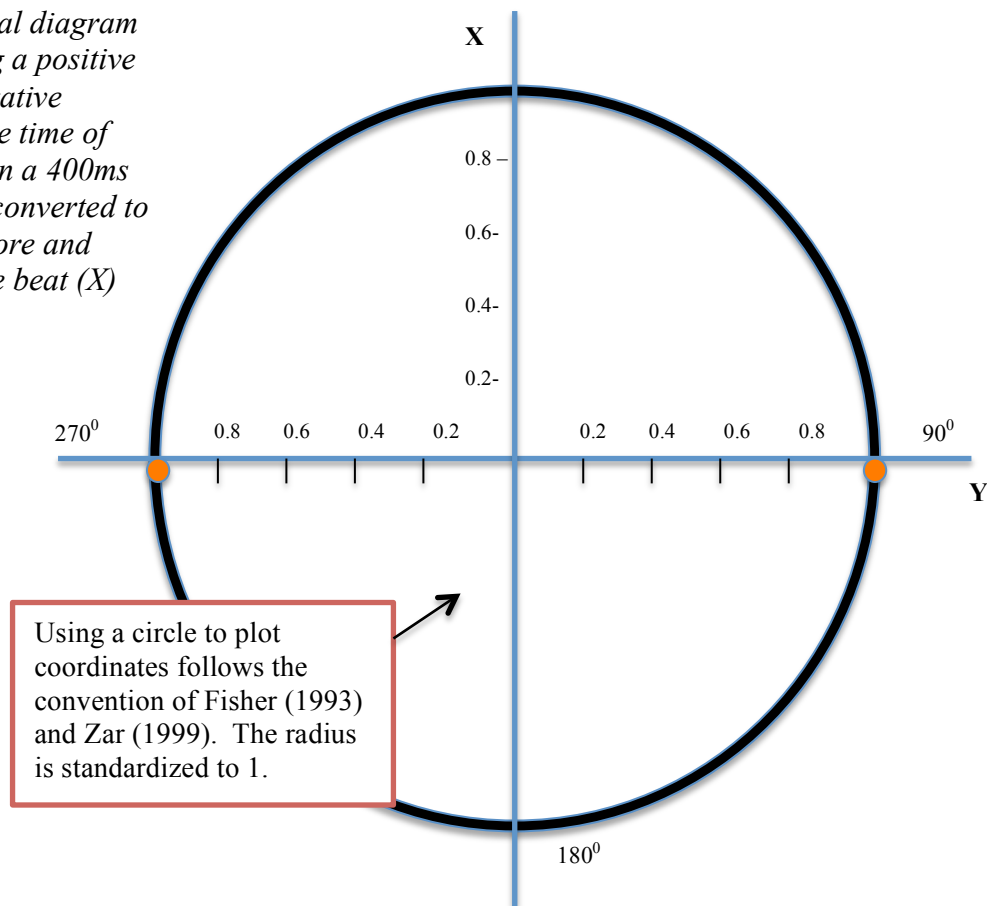
- The pulse rate has an ISI of 400ms.
- The participant taps 100ms after the beat
- This score is then converted into degrees (90^0) degrees.
- Because the circumference of the circle is taken to be 2 radians then this response will be 0.5 radian.

The greatest asynchrony is calculated as 180 degrees from the point of accuracy (0 degrees). Therefore 359 degrees and 1 degree are very close to accuracy (see Figure 7.1.1).

If the participant anticipates the beat then the position on the circumference of the circle will be $360^0 - 90 = 270^0$.

Figure 7.1.1

A circular statistical diagram showing a positive and negative response time of 100ms in a 400ms trial is converted to 900 before and after the beat (X)



From the tapping responses one can calculate the ‘mean vector rate’. This has two non-parametric components, the mean direction Θ , which is analogous to the mean asynchrony, and R , the mean resultant length. R always varies between 0 and 1 and is inversely related to variance in asynchronies. An R of 1 implies that responses are always in perfect synchrony.

The mean resultant length R therefore shows how accurately the participant tapped over the musical phrase (in this case 16 beats in length) as the music went on when neutralising whether the child anticipated or followed the beat, and one can see whether there was an improvement or loss of accuracy within the task. Figure 7.1.2 gives a linear representation of a circular statistical analysis showing the mean performance of the participants in the Full Sample tapping to a metronome at 500ms. The chart shows that at the beginning of the trial the participants start by tapping after the beat, but as the trial progresses they begin to anticipate the beat. At this pulse rate there is accurate entrainment to the metronome with less than 3 degrees variation.

Figure 7.1.2

A linear representation of a circular statistical phase analysis showing the participants performance in relation to zero over 16 data points.

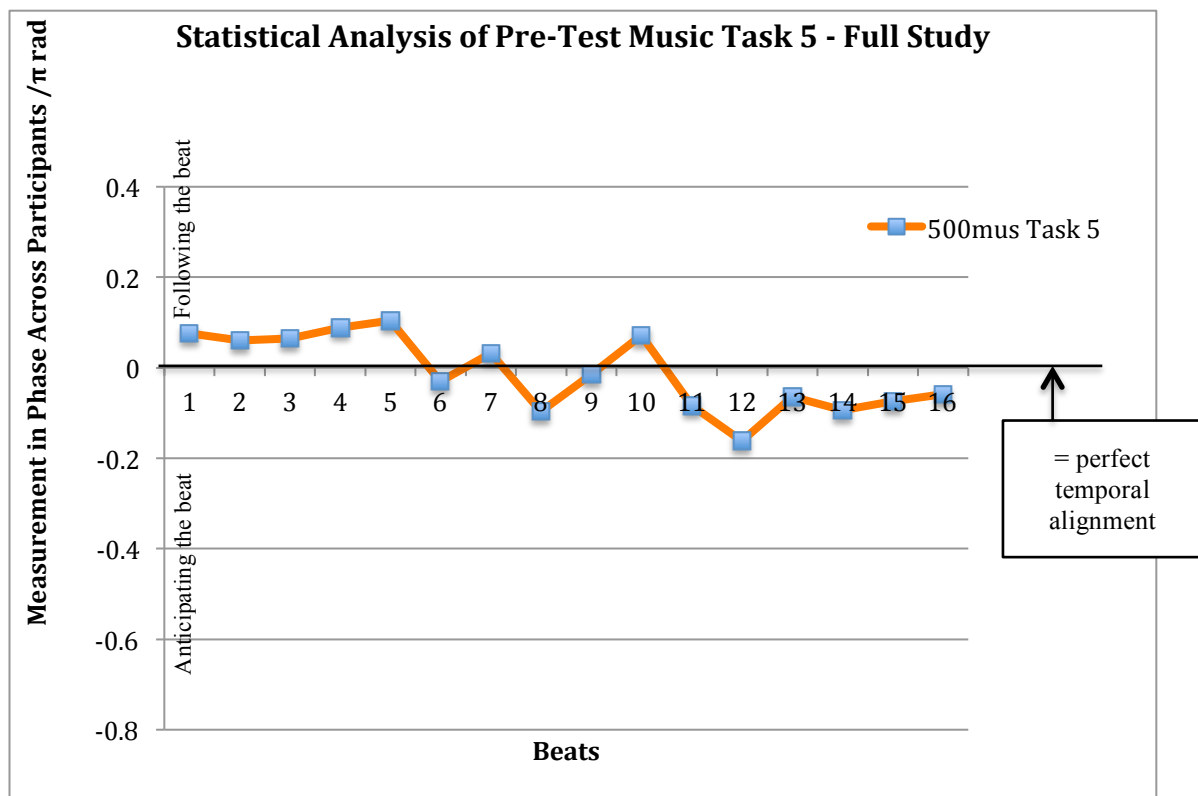


Figure 7.1.3
A circular statistical analysis showing the linear data below on a circle. The dots represent points 1 and 16 shown in the linear diagram.

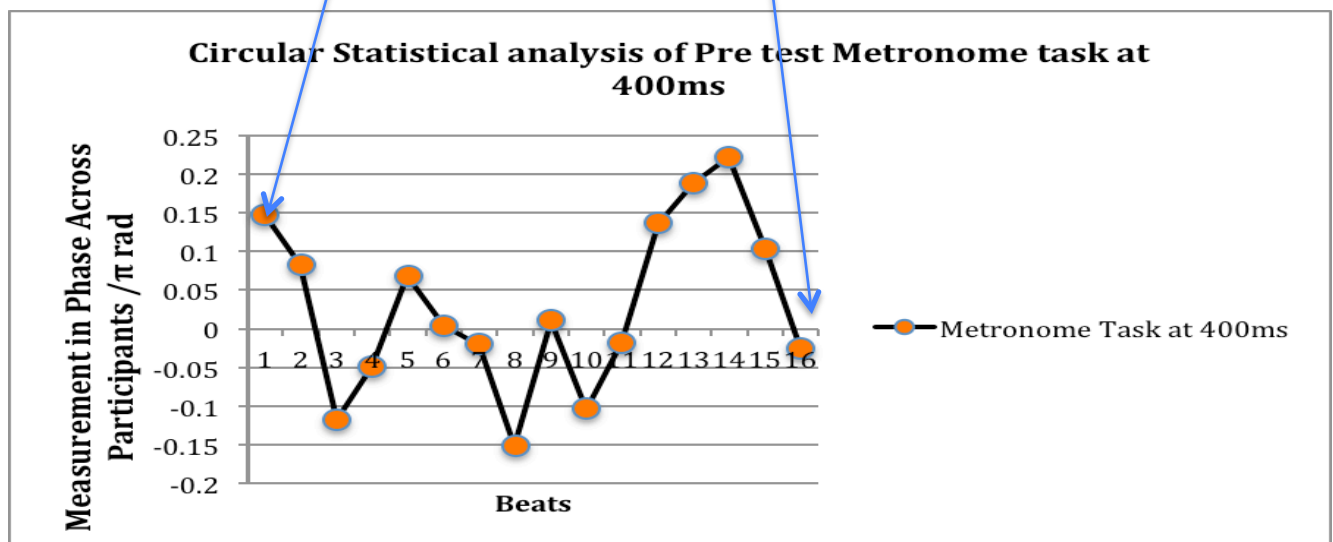
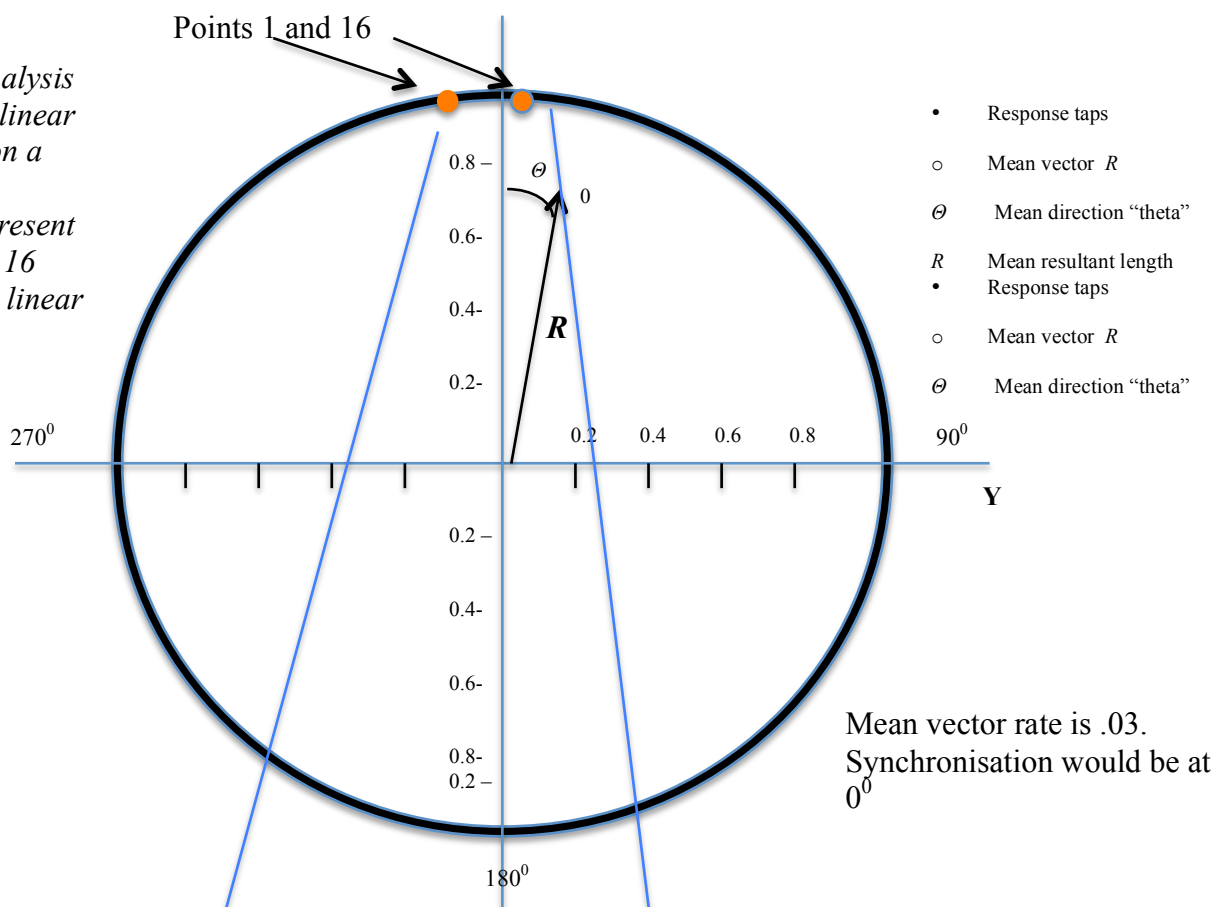


Figure 7.1.3 shows how the linear data are transformed into data points on a circle. The diagram also shows how accurate the child performs by the angle and length of the arrow R . The length and position of the arrow summarizes the child's performance during the task (i.e over 16 beats). The direction of R gives a graphic representation of the mean direction θ (theta) of all response beats, equivalent to the mean asynchrony in linear statistics. The length of R termed mean resultant length R , goes from 0 to 1 and is an inverse measure for the variance of asynchronies during that particular task; the higher the R , the smaller the variance of asynchronies, indicating higher synchronization accuracy. To simplify understanding both circular and linear representation is given in Figure 7.1.3.

7.2 Results of the beat alignment tasks compared in both linear and circular statistical analyses

In this thesis data to be converted into a circular statistical analysis could only be taken from the drumming tasks to metronome and music because it was only in these tasks that sufficient data (16 beats) were collected from the children's responses. In the singing tasks the analysis was only on specific data points where synchronisation (beat alignment) was measured against a small number of data points related to syllables or rhymes within the phrase of music so no analysis of entrainment was possible.

First an analysis of the data from the full study using the anticipation and delayed error alignment scores (Table 7.2.1.) is given and then compared to the results found in the circular statistical analysis. (Table 7.2.2).

a) Full study data analysis using a linear statistical method

The analysis using the reconfigured mean scores from the original data, taking into account anticipation or delay in response, is directly in line with expectations provided by data in both Studies 1 and 2. A One-way ANOVA was computed from the metronome and music scores shown in Table 7.2.1 to see whether there were any differences between performance between the metronome and music tasks at the 4 rates in comparison to previous analysis. In line with expectations the results confirm that there were statistical differences

at the rates of 400 and 500ms and as the pulse rates become slower the children's performance becomes more predictable – eg they perform with greater inaccuracy. The graphic representation in Figure 7.2.1 shows immediately that there is a larger deviation from the pulse point:- re-synchronisation in both the metronome and music tasks as the pulse rate becomes slower. This new analysis however shows that the children are more accurate when drumming to the metronome at the quicker rates (400 and 500ms) than when they drum to music, but more accurate at the slower rates when the pulse rates are supported by music. The accuracy across phase in the drumming to metronome task at 400ms was only 1 millisecond from absolute synchronisation (Table 7.2.1).

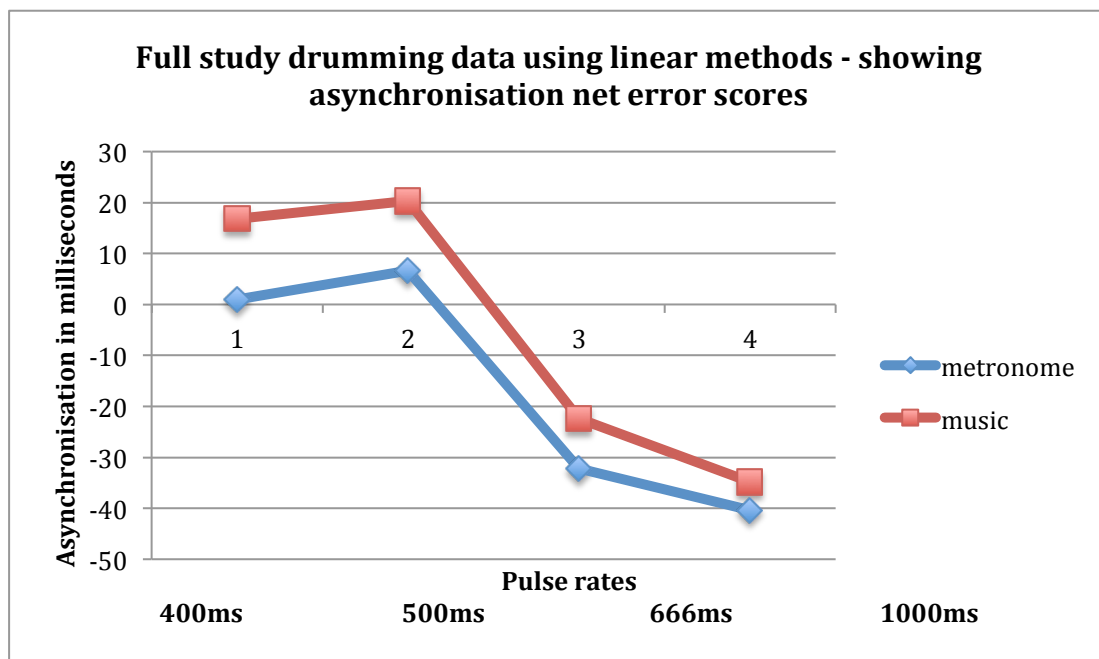
The visual representations in Figures 7.2.1 emphasise the differences.

Table 7.2.1.

Comparisons between phase accuracy tasks in the full study (mean in ms) drumming tasks, with standard deviations and total N in square brackets.

Pulse Rate	400 ms	500 ms	666 ms	1000 ms
Linear phase analysis	1.0	6.6	-32.2	-40.4
Alignment to Metronome scores (before and after the beat)	[62.5, 163]	[70.6, 184]	[87.3, 177]	[141.4, 165]
Alignment to Music	16.8 [52.1, 174]	20.3 [69.0, 179]	-22.4 [74.2, 170]	-34.8 [103.1, 134]
One-way ANOVA	$F(1,334)=6.77,$ $p = 0.01$	$F(1,360)=3.79,$ $p = 0.05$	$F(1,344)=1.3$ $p = 0.3$	$F(1,296)=1.9$ $p = 0.7$

Figure 7.2.1



Because I am using data collected in a linear fashion I can correlate these scores with the Phonological measures.

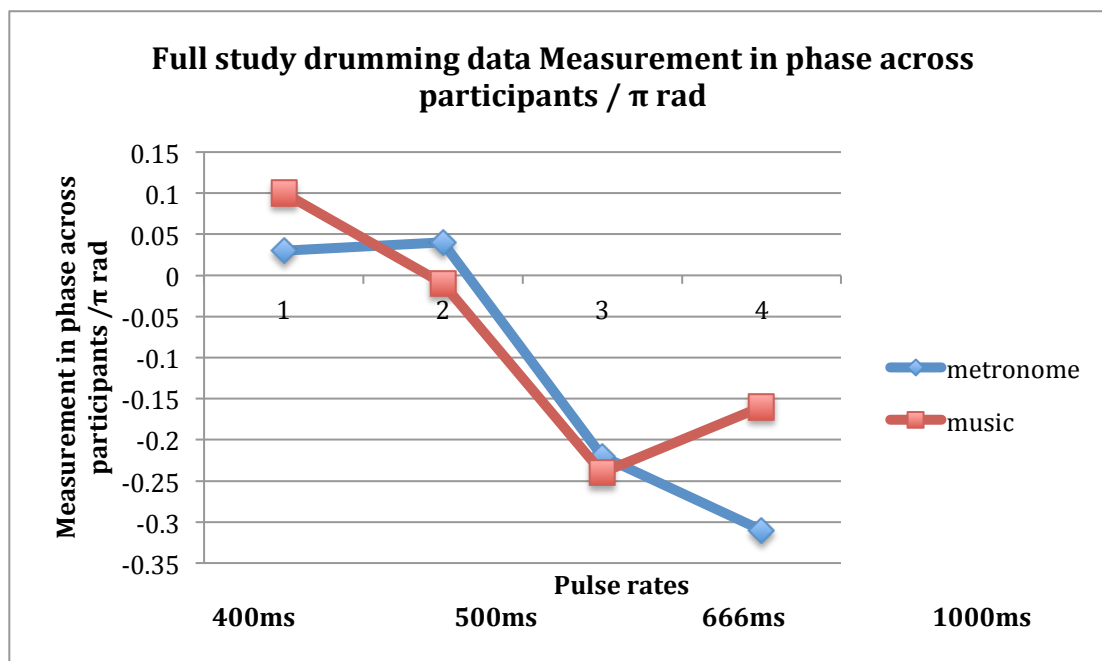
Pearson's bivariate correlations show significant positive correlations only at the pulse rate of 500ms in the metronome tasks.

There was a significant correlation between this rate and Oral Rhyme task ($r = 0.291$, $N = 155$, $p = 0.0001$) and a significant correlation with the Oral Syllable task ($r = 0.192$, $N = 173$, $p = 0.11$).

(b) Full study data converted to mean vector rates for analysis using a circular statistical method

After the data were converted into the mean vector rates the analysis shows a slight difference from previous results. The graphic representation in Figure 7.2.2 shows that the trends seen in Figure 7.2.1 are replicated, particularly at the rates of 500 and 666ms. There are slight differences at the 400ms and 1000ms rates. Note that the graphic representation shows particularly large variations between rates because the scale divisions are much smaller when computed into degrees of the radii.

Figure 7.2.2



At the slower rates (1000ms) where we have seen consistently poor performance across all tasks the circular statistical method foreshortens the differences in scores when one takes into account inaccuracies before and after the beat. The trend for the metronome scores however is still remarkably similar to that shown in the linear analysis.

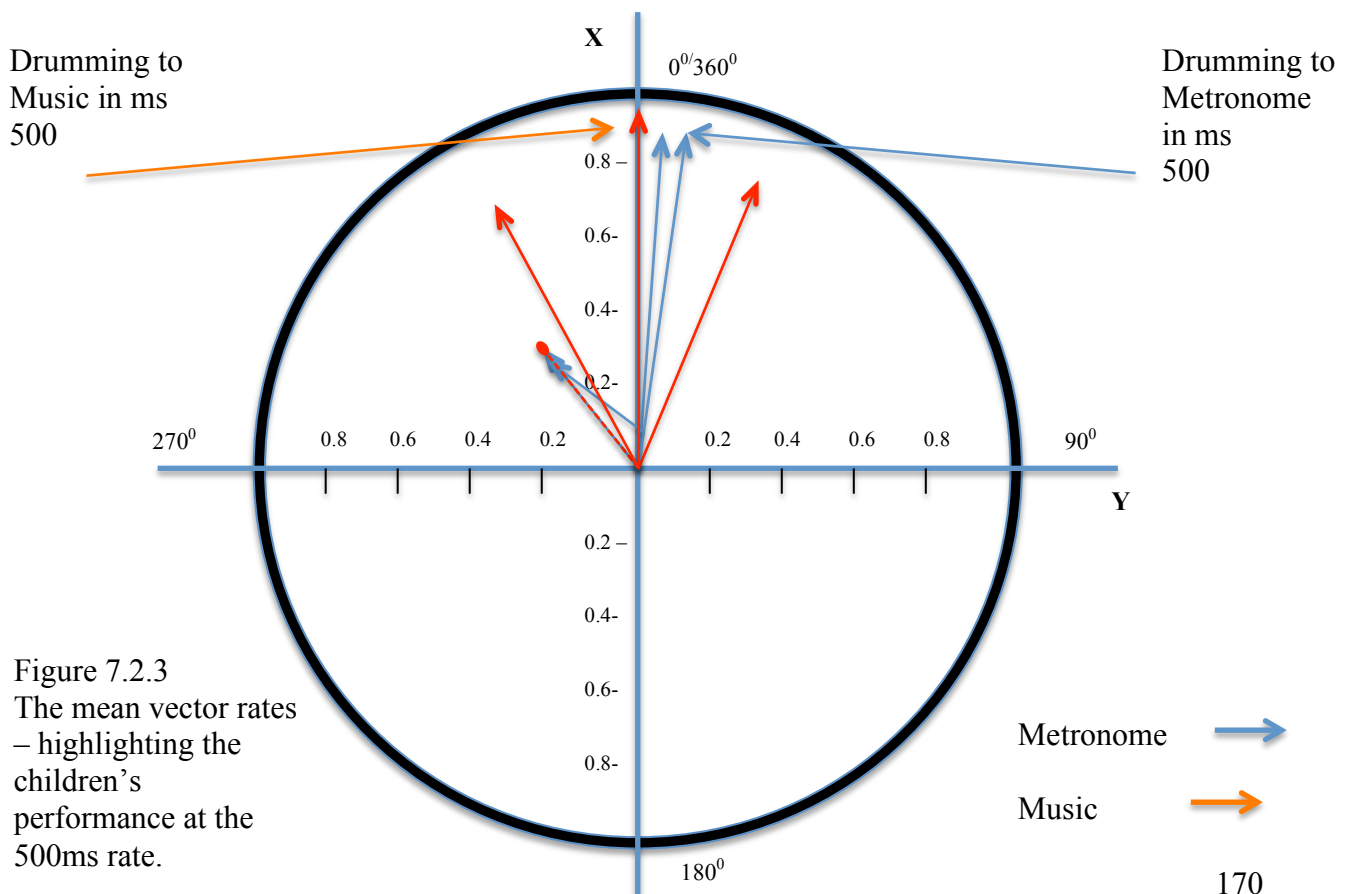
Table 7.2.2 Mean Vector Rate for Full study Metronome and Music Drumming Tasks . (SD in italics)

Table 7.2.2 Drumming in phase comparisons using data in mean vector rates				
	400ms	500ms	666 ms	1000ms
To metronome	0.03 <i>0.11</i>	0.04 <i>0.12</i>	-0.22 <i>0.09</i>	-.31 <i>0.11</i>
To music	0.1 <i>0.09</i>	-.01 <i>0.08</i>	-0.24 <i>0.09</i>	-0.16 <i>0.11</i>
One-way ANOVA	<i>F(1,30)=3.60</i> <i>p = 0.07</i>	<i>F(1,30)=2.04</i> , <i>p = 0.16</i>	<i>F(1,30)=0.50</i> <i>p = 0.50</i>	<i>F(1,30)=15.77</i> <i>p = 0.001</i>

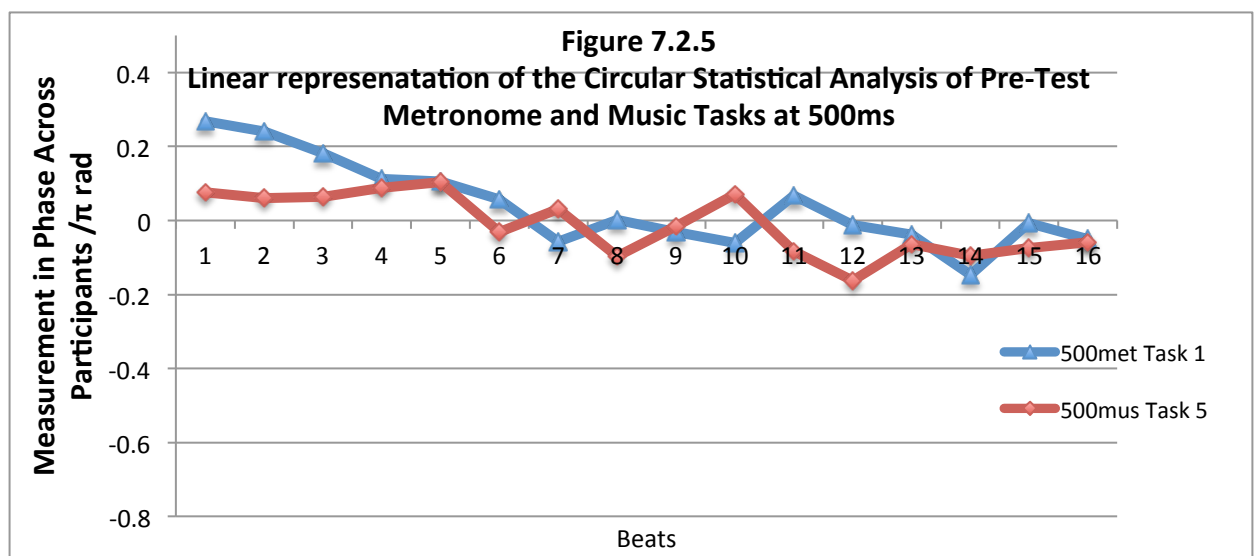
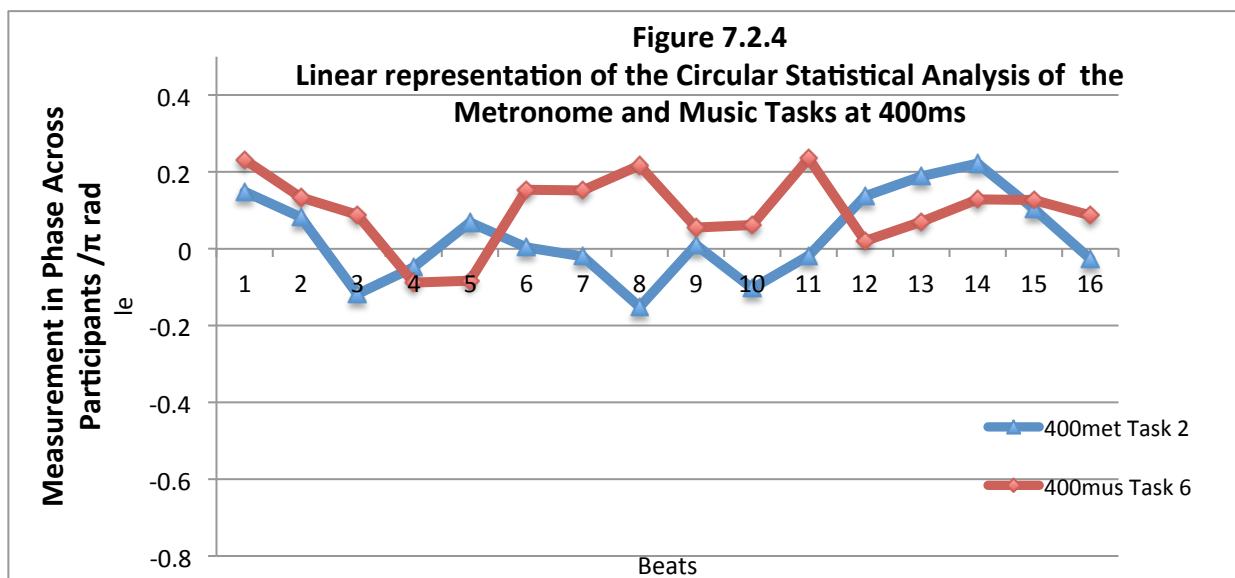
A one-way ANOVA shows that there were no significant differences between the metronome and music tasks at the 500 and 666 rates, but there was a significant difference at the 1000 ms rate ($p < .0001$). There was a near significant difference at the 400ms rate. ($p = 0.067$). These results show once again that the stimulus does affect the performance, especially at the slower rate.

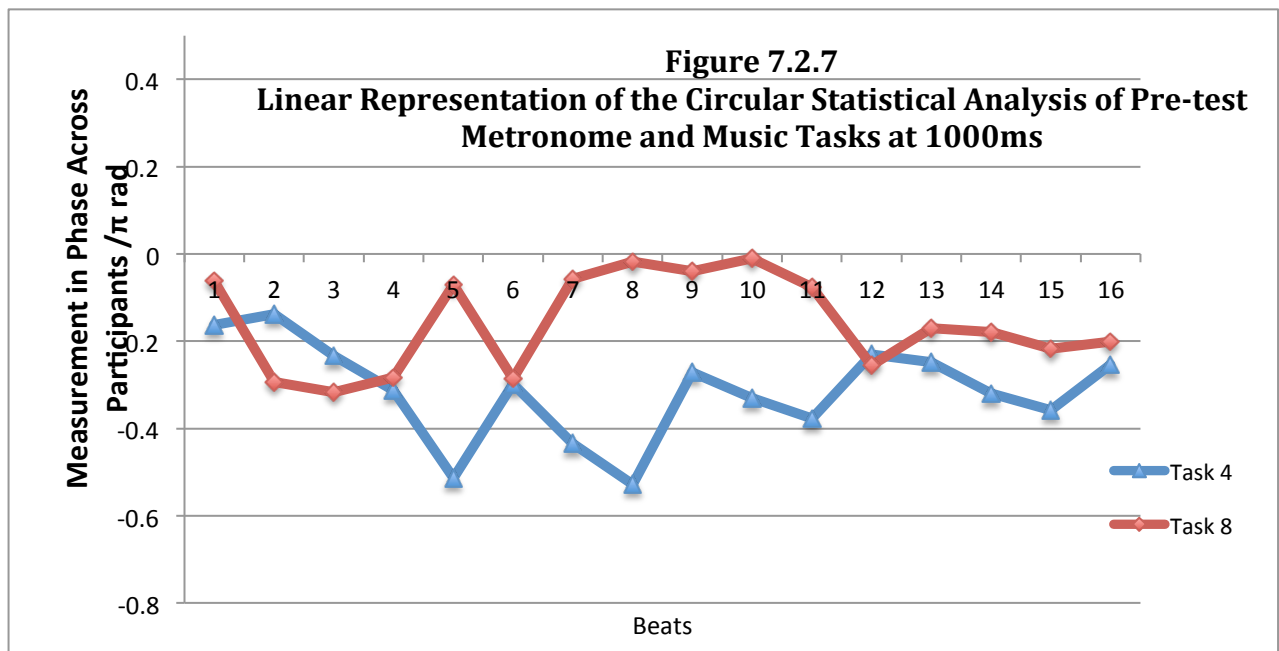
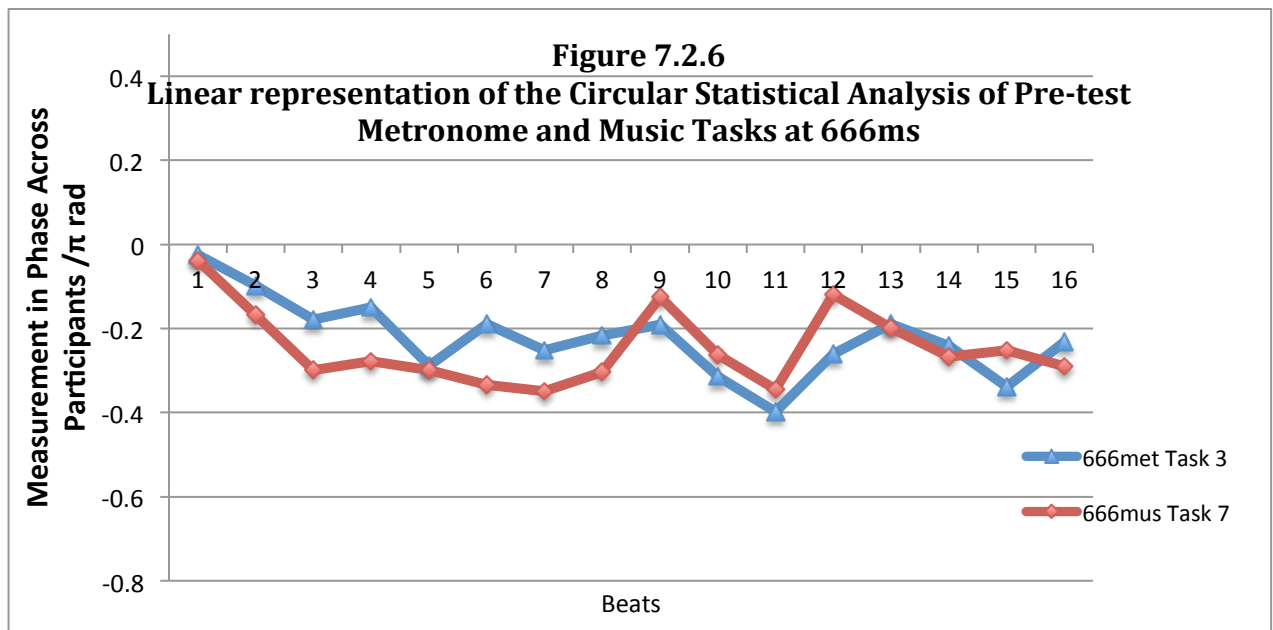
The phase analysis, using the mean vector rates data, shows that the children are most accurate when entraining whilst drumming to music at the 500ms rate. Their mean vector score across the phase of all 16 beats, the equivalent to an asynchronous score in linear, was -0.01 away from perfect synchronisation. The circular statistical analysis therefore gives considerable weight to the hypothesis that there is an optimal speed of response when young children tap along to rhythmic stimuli, and they can be equally accurate whilst drumming to music or a metronome.

Figure 7.2.3 shows the analysis presented in Table 7.2.1 and Figure 7.2.2 in a circular statistical representation and clearly shows the accuracy of the children's performance in both the 500ms Drumming Tasks.



The figures used in the overall phase analyses in Figures 7.2.1 and 7.2.2 are the mean for the trials. The following scores in the Figures 7.2.4 -7.2.7 are computed from the mean score of the trials across all 16 beats. They show clearly that the children performed the trials at the 400 and 500ms rate with much more accuracy. At the 400ms rate there is a tendency for the children to delay their beats. This is in direct line with the findings of Kirschner and Tomosello. They are most consistent at the 500ms rate.





At the slower speeds of 600 and 1000 milliseconds the children anticipate the beat. They are slightly more accurate in the tapping to music condition, than when they play to the metronome. Once again these results are in line with previous research. (Pfordresher, & Dalla Bella (2011).

The most significant pointers that come from the analysis using the revised circular statistical methodology is that the results confirm the theory that the 500ms rate is preferential. It is the rate at which the children's tapping to music or the metronome is most closely matched, and the rate at which the children drum with the greatest degrees of accuracy.

Chapter 8 Study 2 - The Intervention programme

The intervention study reported here was designed to answer the research question (No 6 pg 95 Chapter 3) that asked whether it was possible to ascertain whether a full musical experience, which included rhythm, pitch, harmony and timbre, could enhance a child's phonological skills and be comparable to a language based intervention. Children's playground games have used chanting rhymes to support all kinds of games for centuries, especially ones that need a steady beat to enhance activities such as skipping. Therefore it was decided to also make the language intervention rhythmic. Rhythmic speech can be manipulated with varying pulse rates, in exactly the same way as music. It can be spoken in a near isochronous manner in the same way that occurs in music. Hence the question explored was whether there would be any differences between the impact of music versus rhythmic speech, and indeed if either of these types of training would be more effective than the school phonics lessons which continued in the control group.

A three-group intervention study was therefore devised. Two groups were assigned additional rhythmic training in either music or speech based form, and a further control group received no additional support, but carried on with their normal phonics curriculum.

8.1 *Participants and Methodology*

The final intervention groups had 30 participants in each group. 9 children were previously eliminated on the basis of their WPPSI scores – 3 very high scores (135, 135, 144) and 6 low scores (83, 83, 83, 74, 68 and 65). Classroom sizes in these small village schools are very small, and in order to make the numbers in each group even the class in school 1 had to be divided into two groups. 6 children were included in the 'rhythmic speech' intervention group, and the remaining 10 children were assigned to the Control group (Table 8.1.1).

<i>Table 8.1.1</i>	<i>Numbers of children in each of the three groups in Study 2 of PhD study</i>							total
Groups	School 1	2	3	4	5	6	7	
Speech	6	0	0	0	0	11	13	30
Music	0	0	0	14	16	0	0	30
Control	10	6	14	0	0	0	0	30

It was important to make the rhythmic speech programme equally engaging and have elements that could be compared with the music intervention. Initially, following analysis of the literature, a programme devised by Carroll and Snowling et al (2003) was considered because their tasks involved puppets in a way similar to that used in the Treiman tests and in the researcher's work with 'Pat the Panda' – the cuddly toys acting as catalysts for the children's responses. However the Carroll and Snowling's training programme was devised for slightly younger children whose ages ranged from 3 years 2 months to 4 yrs 5 months. It was designed to test whether the development of phonological awareness follows the progression of syllable, then onset and rime, and then to phoneme. In the end it was not chosen for this research because there were few directly comparable features with the rhythmic tasks in the music programme.

A novel rhythmic speech intervention programme was devised, based on the musical intervention. The principle difference between the two programmes was that one involved music using instrumental backing tracks and singing, and the other did not. The rhythmic speech intervention used normal speech prosody, but still maintained the rhythmic nature of the songs – 'choral speech' or 'chanting'. Some of the visual material and games used in both programmes came from the intervention strategy 'Sounds Great'³⁷ described in Chapter 1.

8.1.1 Pre-tests and Post-tests Intervention timetable

As stated in Chapter 5 all the data collection, analysis and tests described in Study 1 were repeated in Study 2. The familiarisation pre-test sessions were identical and took place in November after the children had

³⁷ Sounds Great – Nicholson, Lumsdon, Verney et al (2002) Northumberland Education

been in school for 7 weeks and were comfortable in their class environment. The pre-tests, intervention programmes and post-test commenced immediately after the Christmas holidays (Table 8.1.2).

<i>Table 8.1.2</i>		<i>Study 2 Timetable commencing November 2010</i>	
Weeks	Comments	Time	
1 – 3	A visit each week to the schools for familiarisation lessons	30 minutes	
4 – 6	Assessment Testing	12 minutes	one day
	Music Tapping Test	10 minutes	one day
	Singing Test	10 minutes	one day
7 – 9	WPPSI	10 minutes	one day
	Pre-testing		
	Oral rhyme and Picture Rhyme	12 minutes	one day
	Word Recall and Picture Syllable	12 minutes	one day
	Oral syllable test (+catch up)	12 minutes	one day
10 – 16	Intervention Activities	2 x 15 minute sessions each week	
17 – 20	Post-testing :- Rhyme and Syllable tests. J.P. Verney Rhythmic Pitched Test BAS reading test		

The two intervention groups received two weekly visits (Tuesday and Thursday) each lasting for approximately 20 minutes. The small group of 6 in the ‘speech’ group generally received 15 minutes at each visit.

8.2 The Music Intervention. (For full lesson notes see appendix G)

The music programme was designed to draw specific attention to how the syllables in the words of the songs matched a note in a melody, and how rhymes were positioned at the end of each musical phrase. All of the songs and music had been successfully trialled with many thousands of children over a period of 15 years in the context of early- years music lessons and were songs that the children had always learnt quickly.

Neither syllables nor rhymes were being taught as part of the programme of literacy in any of the schools so the concepts were new to the

children. The focus of attention in the child's literacy curriculum was almost exclusively on learning letter sounds.

The familiarisation pre-test sessions devised to help the children with the music tasks had proved to be engaging for the children, so the music programme followed the same pattern with a combination of full class activities and individually targeted activities.

8.2.1 Musical activities for Syllable Training

For training in the syllables three bags of cuddly toys were the main focus and catalyst of interest. They were called 'syllable bags 1, 2 or 3'. Each contained a variety of animals with matching syllable lengths – Bag 1 might have a bear, a duck or a snake etc – Bag 2 could contain a panda, rabbit or donkey, and Bag 3 could have a ladybird or an elephant etc. Before

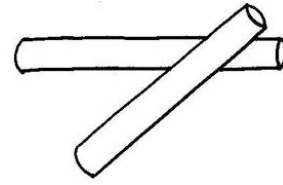


they could play the game they had to know the word syllable and be able to tap out its component parts:- syl –la –ble.

(The children always referred to the Mouse as 'Mickey Mouse' therefore 3 taps)

As each animal came from the bags the children would sing the 'Hello song' to it – matching a syllable to every note of the song. As a further focus to the note matching the trainer or the children would play the song using three chime bars (C D or E). As a further cue to syllable matching simple

claves³⁸ were made so the children could tap them together on each syllable – they were called ‘syllable sticks’.



Using these, the children could tap along to other tunes or try and match special groups of words in songs eg ‘clippety clop’ from the nursery rhyme ‘Horsey Horsey’ or ‘rat -a -tat- tat’ from ‘Miss Polly had a Dolly’.

A series of flash cards were also used (from ‘Sounds Great’ see appendix G. pg. 39) to help play and sing ‘Hello’ games and to match syllable construction. They were also grouped into three sets of animals focusing on the number of syllables in the animal’s name.

A tune that the children had heard in the familiarisation pre-test sessions was now used as a target song. In ‘Marching through the Jungle’ (see appendix D) the children had to choose which animal they would like to march with. Each of the animals came from one of the three bags – and so the syllable beats were further discussed as the children marched and sang to the song.

Tapping and ‘marching on the spot’³⁹ was promoted by this song and another called ‘It’s my school music day’. The title could be modified to different schools – eg “It’s London Music Day’ or ‘It’s Manchester Music Day” (see Appendix D It’s Nursery Music Day). The children tapped along in time using different musically instruments such as the mini-maracas or bongo drums.

8.2.2 Musical activities for Rhyme training

a) Familiar Songs

The song ‘Mickey the Mouse’ was taught initially to help the children tap at a pulse rate of 500ms. Various instruments can be used – the whole

³⁸ Claves are heavy wooden sticks tapped together used in afro- Caribbean music – they make a very dynamic clicking sound. The lighter version used in schools are sometimes referred to as ‘rhythm sticks’

³⁹ Children of this age, who have been in school for a very short time, find marching in time in a circle around a room very difficult. Marching on the spot is rhythmically much more accurate.

class can use mini-maracas⁴⁰, and a targeted child can be watched to observe rhythmic accuracy as they play the bongo drums.

The words are then recalled from the familiarisation pre-test session, but as part of rhyme training – the rhyming word was emphasised or by omission – eg ‘Mickey the Mouse he plays music all round the _____. The children have to make sure they don’t sing the rhyming word. The task was repeated whilst the children listen to the music on a CD – and this time they just have to sing the rhyming word and nothing else.

This technique was then used with the other familiar nursery rhymes used in the pre-tests. (Twinkle, Twinkle; Polly had a Dolly; Baa, Baa Black Sheep and Hickory Dickory Dock had all been chosen as examples to use in the testing and training sessions because they were the most often used songs in the children’s repertoire.)

The children pretend to sing the rhyming words into their pretend microphones (the mini – maracas) – Twinkle Twinkle little star: How I wonder what you _____. In the case of ‘Miss Polly had a Dolly’ the children can tap the rhyming words with instruments – ‘sick, sick, sick’ and ‘quick, quick, quick’.

In the rhyme training 2 new songs were also taught:- Rocky the Rabbit and the Soldier’ Song. (see Figure 8.2.1.).

b) New songs

Rocky the Rabbit is then taught because it has a structure that is adaptable to changing the rhyming words at the end of each phrase. It can also be linked to a dance. The children pretend to play the focused instrument – guitar – drums etc, and then they dance like a rock star; shake their bottoms whilst they ‘shimmy like a sheep’; and sing into their pretend microphones etc.. The trainer then omits the rhyming words and the children have to put them in place on the correct beat in the music. Changing the name of the instrument modifies the song, and then the children have to find

⁴⁰ When tapping the children use just one maraca and tap against the other hand – they are not used as shakers.

a rhyming word for the new instrument. This song can lead to great fun for the little children, as invariably drum rhymes with ‘bum’.

Figure 8.2.1 Music Intervention Training Songs

John P. Verney

Rocky the rabbit

$\text{♩} = 120$

Bluesy Swing

Rock - y is a rab - bit and he plays the gui - tar. He

dan - ces on the stage 'cause he is a rock star. He shim - meys with the sheep and he

sings with the deer. He's the great - est rab - bit that you'll ev - er hear.

John P. Verney

The Soldier's Song

The sold - ier marched a - round with a

hat up - on his head. A

hat up - on his head; with a

hat up - on his head. The

sold - ier marched a - round with a

hat up - on his head And the

drums went rat - a - tat tat.

Fun is also a feature of the rhyming game that goes with the next new song ‘Soldiers Song’ (Figure 8.2.1), because the rhymes are emphasized by the children creating inappropriate rhymes that don’t make sense. The children are taught the marching song⁴¹ :-

*The Soldier marched around with a hat upon his head (x 3)
and the drums went rat – a – tat –tat.*

The children are encouraged to find new words that rhyme with the key words ‘Hat and Head’. The first change could involve changing ‘hat’ with ‘bat’, and then the words would be:-

*The Soldier marched around with a bat upon his head (x 3)
and the drums went rat – a – tat –tat.*

Depending on what kind of bat the children imagine – flying or sport related- the song has become ‘quite silly’. Each new change comes with a change of action, and the children always march along with the song in time to the music.

c) Flash card games

A set of rhyming flashcards was used to change words in the songs. First the children played a game of matching the cards so they were familiar with the paired rhyming cards – sock/ clock; star / car etc... They could then sing ‘Rocky the Rabbit’ song, but this time they had to devise new words by changing the rhymes using the flashcard pairs. The nonsense idea was used again to appeal to the children’s sense of humour. They found it funny to sing” Rocky is a Rabbit and he’s got a clock – he keeps his clock inside his sock.

During the improvisation of the songs no backing tracks were used, but because of the researcher’s musical experience the speeds were maintained at the correct pulse rates.

⁴¹ In the music tasks the IOI for this tune is 666ms, but in the intervention it is changed to 500ms.

All sessions last approximately 20 minutes and begin and finish with a ‘Hello or Goodbye song’, sung with the chime bars and. (Table 8.2.1)

<i>Table 8.2.1 Comparing the Rhythmic Speech and Music Interventions Lesson Time Table</i>			
	Music session	Speech session	Time
	Introduction Sing & Play Hello Songs	Hello greeting chanted and waved	3 mins
	Flash Card recognition for syllable or rhyme awareness	Flash Card recognition for syllable or rhyme awareness	5 mins
	Revise known songs	Revise known poems	3 mins
	Learn New Song	Learn new poem	7 mins
	Goodbye Songs	Goodbye chant and wave	2 mins

8.3 The Rhythmic Speech Intervention

The Rhythmic Speech intervention matched as closely as possible the music training. All the songs that were used by the music group were used again, but were chanted without a musical pitch. The pulse rate was maintained at an IOI of 500ms whilst chanting, matching as closely as possible the speed of singing in the music group. Prosody was not exaggerated whilst chanting and singing was assiduously avoided. No music was played at any time.

The intervention lessons were matched in terms of overall time, and time spent on each activity (Table 8.3.1). The same flash cards, animal sacks, and tapping sticks were used. The mini-maracas were also used, but only as a pretend microphone rather than as a percussion instrument. The same techniques of involving the children and carers were used in all cases to maintain an equal blend of humour and enthusiasm within the lessons.

The opening ‘Hello’ greeting was associated with a simple song since it had been used in both the familiarization sessions and the music tasks during testing. In order to stop the children trying to sing it, a new form of

the greeting had to be learned. The change of pitch associated with the song was substituted with an increasingly active wave on the repeated passages of the words. In the song there were three chime bars ascending in pitch (C, D and E), but in the chant there were three ways of waving which gradually became more enthusiastic as the arms were raised.



When the children found an animal from the syllable bags they simply said ‘Hello Mr Panda’ in a conversational way.

The syllable sticks, that had no specific tuned pitch, were used to tap out the number of syllables in a target word. The flashcards were used in the same way as in the music intervention, but more emphasis was placed on playing ‘animal snap’. The trainer simply placed one card on the floor, and then revealed cards at random until one emerged from the pack that matched the target syllable card. A variation was to give all the children a card and then the remaining cards were placed on the floor at random and then individual children had to find one that matched with their card.

Similar games could be played using the rhyming sets. Three cards were placed on the floor – two of which rhymed, and the children had to identify the ‘odd one out’.

Lesson notes (appendix G) show the variation in the order of presentation of the material.

Chapter 9 Results from the matched group intervention

9.1 The Matched Group Intervention

The groups were initially divided from the 99 participating children into three groups of 30. Nine children were eliminated on the basis of their very high or low IQ scores (see chapter 8 for details). Three further tests were used from pre-test data to establish the matching nature of the three groups:- performance on the psychometric measures, and two measures of musical aptitude – drumming and singing. It was important to establish that no one group had superior performance in these measures, as they were to form the basis of training.

Table 9.1.1 Participant details in the matched groups

	Speech (N 30)		Music (N 30)		Control (N 30)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Age in months	57.9	(3.2)	57.0	(3.8)	56.7	(3.8)
CLL	45.7	(7.5)	42.1	(5.9)	43.0	(5.4)
FSP	52.0	(4.5)	53.0	(5.0)	52.0	(4.0)
WPPSI	109.8	(12.1)	109.1	(9.1)	106.0	(11.9)
WORD RECALL	104.3	(11.7)	104.5	(13.0)	107.4	(11.4)

a) Pre-test analysis comparing groups in the psychometric measures

The mean scores and standard deviations in all the cognition tests are presented in Table 9.1.1. After outliers were removed from each group participants' performance was compared using a 3 x 4 (Group: Rhythmic Speech, Music, Control) x Task: CLL, FSP, WPPSI & Word Recall) One-way ANOVA. The group was the between subjects factor and the tasks were the dependent list. The ANOVA showed no statistical differences between groups in any of the tasks:- CLL ($F(2,84) = 2.5, p = 0.09$); FSP ($F(2,83) =$

0.4, $p = 0.64$); WPPSI ($F(2,86) = 0.95$, $p = 0.4$); Word Recall ($F(2,85) = 0.6$, $p = 0.55$).

b) Pre-test analysis comparing groups in the drumming tasks

A measure of the children's musical behaviour was based on their beat alignment drumming scores. These were computed from their combined pre-test scores in both metronome and music tasks. Missing values in the data were replaced by median scores. Group descriptives are shown in Table 9.1.2

After outliers were removed from each group participants performance was compared using a 3 x 4 (Group: Rhythmic Speech, Music, Control x Rate: 400ms, 500ms, 666ms and 1000ms) repeated measures ANOVA. Group was the between subjects factor and Rate the dependent variable. There was no significant main effect of Group ($F(2,87) = 7.3$, $p = 0.5$). As expected there was a significant main effect of Rate ($F(3,261) = 136.8$, $p = 0.0001$). There was no significant effect of interaction between Group and Rate, ($F(6,261) = .7$, $p = .65$).

Table 9.1.2 Beat accuracy (mean in ms) by rhythmic entrainment task, based on pre-test mean scores of drumming to both metronome and music combined.

	Rhythmic Speech (N 30)		Music Group [N 30]		Control Group(N 30)	
Drumming rates in milliseconds	Mean	(SD)	Mean	(SD)	Mean	(SD)
400	84.9	26.5	95.8	20.3	92.5	26.3
500	78.2	25.1	98.2	26.5	94.0	28.5
666	118.7	39.9	124.7	39.1	114.8	39.0
1000	185.6	73.7	184.0	58.3	188.2	64.9

c) Pre-test analysis comparing groups in the singing tasks

A second measure of the children's musical aptitude was based on their beat alignment singing scores. These scores were computed from their combined pre-test singing scores (Singing in Time and both the – and +

Music Rhyme tasks). Missing values in the data were replaced by median scores. Group details are shown in Table 9.1.3.

Table 9.1.3 Beat accuracy (mean in ms) by rhythmic entrainment task, based on the pre-test mean scores of the Singing in Time and + and – Music tasks combined

Singing rates in milliseconds	Speech (N 30)		Music (N 30)		Control (N 30)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
400	79.3	34.8	85.5	44.0	94.5	36.0
500	55.8	19.4	70.4	31.4	68.2	25.4
666	70.9	21.9	78.9	27.5	74.7	21.8
1000	95.0	35.1	107.3	48.3	95.8	35.4

After outliers were removed from each group participants performance was compared using a 3 x 4 (Group: Speech, Music, Control) x Rate: 400ms, 500ms, 666ms and 1000ms) Repeated Measures ANOVA. Group was the between subjects factor and Rate was the dependent variable. The ANOVA showed no significant main effect of group ($F(2.87) = 1.9, p = .16$). The ANOVA again showed a highly significant main effect of Rate ($F(3.26) = 23.4, p = .0001$). There was no significant effect of interaction between Rate and Group ($F(6,261) = .77, p = 0.6$)

Because the matched groups showed no statistical differences in either the drumming or singing interactions it seemed reasonable to assume that any gains in performance in either the music or phonological awareness post-tests would result from the short seven-week intervention rather than from natural maturation. The inclusion of a third group, which received no additional teaching, controlled for the issue of maturation.

Table 9.2.1 Phonological Awareness by Group Pre and Post-test mean scores

Rhythmic Speech Group (N 30)		Pre-test		Post-test		
		Mean	(SD)	Mean	(SD)	Gains
Oral Rhyme (%)		24.7	14.9	49.6	23.5	+24.9
Picture Rhyme (%)		53.9	21.7	61.3	34.5	+7.4
Oral Syllable (%)		41.3	31.1	71.0	23.1	+29.7
Picture Syllable (%)		15.2	11.5	61.4	26.4	+46.2
Music Group (N 30)						
Oral Rhyme (%)		24.0	20.4	43.2	24.6	+19.2
Picture Rhyme (%)		63.7	23.2	66.0	28,4	+2.3
Oral Syllable (%)		17.4	13.4	66.0	33.6	+48.6
Picture Syllable (%)		19.7	12.9	58.5	26.2	+38.8
Control Group (N 29)						
Oral Rhyme (standardised)		22.1	14.0	33.9	18.0	+11.8
Picture Rhyme (%)		45.6	22.0	54.4	28.2	+8.8
Oral Syllable (%)		34.7	26.1	54.9	35.4	+20.2
Picture Syllable (%)		24.3	13.2	29.9	21.8	+5.6

9.2 Analysis of the group performance in the Phonological Awareness tasks between pre and post-tests

Table 9.2.1 shows the pre and post-test mean scores for the Phonological Awareness tests. The gains shown suggest that the intervention was successful because the scores in both the speech and music groups are considerably higher than the gain in the control group in three of the four tests. The Control group made greater gains than the Music Group in the Picture Rhyme. However the Music Group pre-test score was much higher than the Control. The scores show that the children made greater gains in the syllable tasks than in the rhyme tasks, particularly in the Music Group. To investigate these scores further a series of repeated measures ANOVAs were computed and analysed.

(a) Analysis of the Rhyme pre-and post-test results.

A 3 x 2 x 2 (Group : Rhythmic Speech, Music, Control; Task: Oral Rhyme, Picture Rhyme; Time: pre and post-test) repeated measures ANOVA was used to analyse any differences found in the performance of the groups in the Rhyme tasks between pre and post-testing. The rhyme tasks, calculated in percentage points, were the dependent variable.

The ANOVA showed a significant main effect of group ($F(2,79) = 3.5, p = .04$) and there was also a very close to significant interaction between Task and Group ($F(2,79) 3.1, p = 0.0501$).

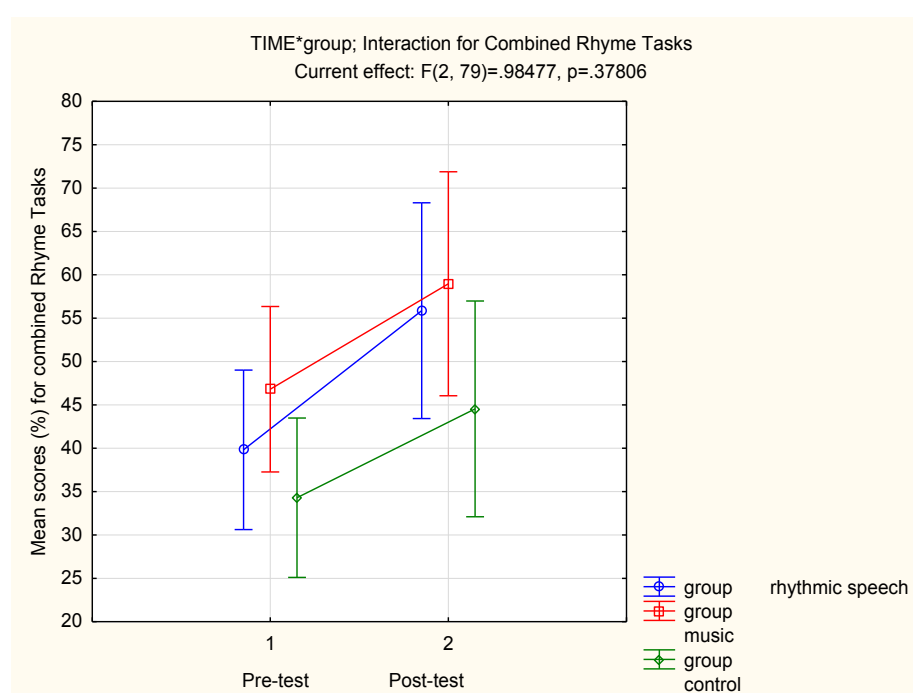
The ANOVA showed a highly significant result for the main effect of Task ($F(1,79)=184.0, p < .0001$). This confirmed that the children all found the Picture Rhyme task easier than the Oral Rhyme task. This result underlies the importance of choosing a variety of tests for the children to find which is most appropriate to their age and ability. The addition of the pictures to support the understanding of the rhyming concept helped their performance in this task. There were highly significant differences found for the main effect of Time between all groups ($F(1,79)=54.3, p<0001$). The Interaction between Task and Time was highly significant, ($F(1,79) = 21.3, p = 0.0001$) and suggests that the intervention helped to increase scores between pre and post-testing. The scores in Table 9.2.1 show that in all cases the post-test scores in both rhyme tasks

improved over time, with particular improvement in the oral rhyme task, which before intervention had proved to be the more difficult task.

However the impact of the intervention was not conclusive because although the ANOVA had shown a significant main effect of group the interaction between Group and Task did not quite reach significance, nor did the interaction between Group and Time ($F(2,79)=1.0$, $p=.38$).

Figure 9.2.1 gives a visual representation of the Time Group interaction in the Rhyme Tasks.*

Figure 9.2.1



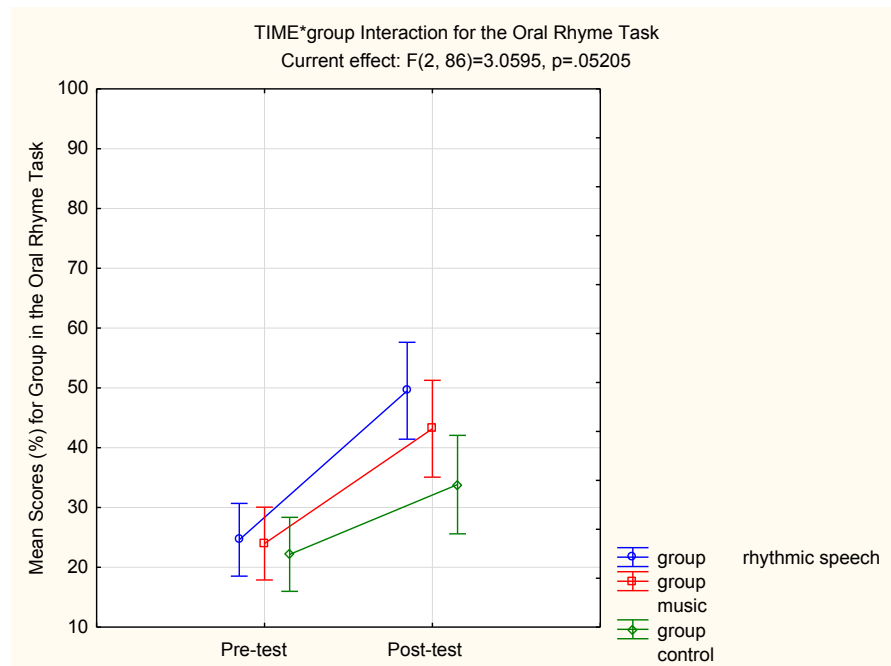
By viewing Table 9.2.1 you can see that the control group made similar gains to the rhythmic speech group in the picture rhyme tasks. Because the Group*Task interaction was at near significance it was considered that separation of the two tasks might reveal more information concerning the impact of the intervention in both the oral and the picture rhyme tasks.

In a 3 x 1 x 2 (Group: Rhythmic Speech, Music, Control; Task: Oral Rhyme; Time: pre and post-test) repeated measures ANOVA I found no significant main effect for Group ($F(2,86) = 2.2$, $p=.12$). There was as expected a highly significant main effect of time ($F(1,86) = 72.2$, $p=.0001$). There was a

near significant interaction between Time and Group ($F(2,86) = 3.1, p = 0.052$) and so a Newman–Keuls post–hoc analysis was computed. It revealed that there was a significant difference in performance at post-test ($p < .01$) between the rhythmic speech group and control, but no significant difference for the speech to music or between the music and control groups.

Hence these results show that the rhythmic speech intervention was more effective than the music intervention in improving children’s understanding of the oral rhyme task. A visual representation is shown in Figure 9.2.2

Figure 9.2.2
Time Group*
Interaction in
the Oral
Rhyme Task



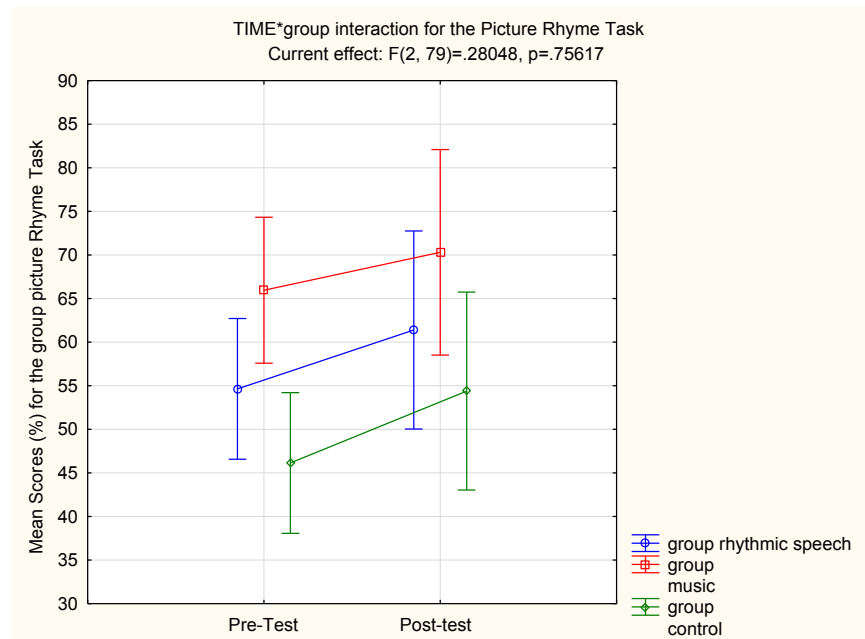
In the Picture Rhyme Task $3 \times 1 \times 2$ (Group: Rhythmic Speech, Music, Control; Task: Picture Rhyme; Time: pre and post-test) repeated measures ANOVA I found a significant main effect for Group ($F(2,79) = 3.6, p = .031$) and a significant effect for the main effect of Time ($F(1,79) = 9.2, p = .003$).

In this analysis we did not find a significant difference in the interaction between Group and Time ($F(2,79) = .28, p = .76$).

This suggests that the intervention did not improve the children’s performance in the Picture Rhyme test in comparison to the effects of normal maturation.

A visual representation is given in Figure 9.2.3.

*Figure 9.2.3
Time* Group
Interaction in
the Picture
Rhyme Task*



One can therefore assume from these results that although the children found the Picture Rhyme tasks relatively easy, the intervention made most impact on improving their oral rhyme perception. The most effective means of achieving this was through the rhythmic speech intervention.

(b) Analysis of the Syllable pre-and post-test results

A further $3 \times 2 \times 2$ (Group; Rhythmic Speech, Music, Control \times Task: Oral Syllable, Picture Syllable \times Time: pre and post-test) repeated measures ANOVA was used to analyse performance of the groups in the Syllable tasks. The percentage correct syllable tasks were the dependent variable.

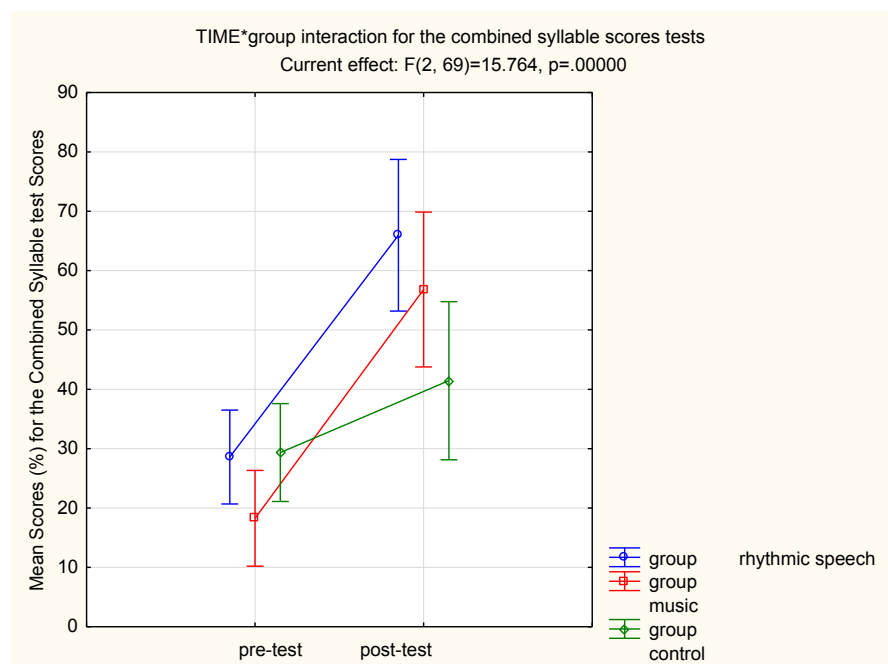
There was a significant main effect of Group ($F(2,69)=3.6$, $p = .03$) and a highly significant result ($F(1,69)=19.4$, $p = .0001$) for the main effect of Task. Table 9.2.1 shows that the scores for the Oral Syllable test in the Music Group were much lower in accuracy than for either the Rhythmic Speech group or the Control Group at pre-test. The interaction between Task and Group ($F(2,69)=4.2$, $p = .019$) confirms that there was a significant difference between the performance of the groups in their ability to perform the different syllable tasks. By looking at Table 9.2.1 one can see that at pre-test the Music group found the

Picture Syllable task marginally easier, whereas the Rhythmic Speech group in particular scored more highly in the oral syllable task. This was confirmed by Newman-Keuls post hoc tests that showed significant differences between the performances of the two syllable tasks in the Rhythmic Speech Group ($p < .0001$) at pre-test. There were no statistical differences between performance by either the Music or Control Group in either of the two syllable tasks in the pre-test.

For the main effect of Time there was as expected a highly significant difference between the performance of the children between pre and post-testing ($F(1,69) = 186.6, p = .0001$). In the interaction between Time and Group there was a highly significant difference ($F(2,69) = 15.8, p = .0001$). Newman-Keuls post hoc tests revealed that there were no statistical differences at post-test for the performance of the Children in the Oral Syllable task between the groups, but there were highly significant differences between both the Rhythmic Speech and Control groups ($p < .001$) and between music and control groups in the post-tests ($p < .01$) in the Picture Syllable Task. There was no statistical difference between the performances of the children after the intervention between the speech and music groups.

A visual representation of this is shown in Figure 9.2.4

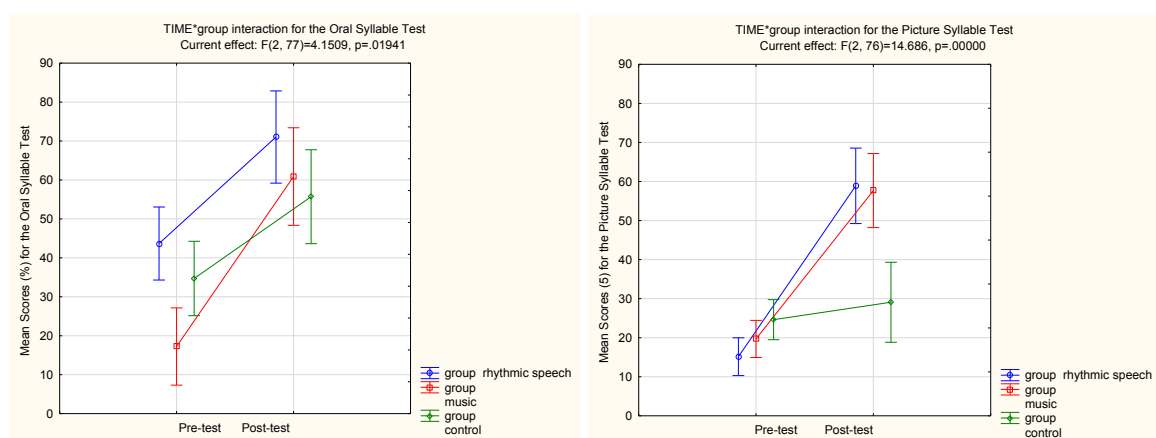
*Figure 9.2.4
Time*Group
Interaction in
the combined
syllable scores
test*



The analyses show that both interventions were successful in the Picture syllable test, because both Intervention Groups outperformed the control. However there was no difference between the effects of the Rhythmic Speech Group and the Music Group; they were equally successful. The interventions were less successful in the Oral Syllable Tests, neither showing considerable gains over the naturally maturing Control Group. Once again there was no statistical difference between the effects of the Rhythmic Speech and Music Groups.

Visual representations (Figure 9.2.5) of these results are taken from analyses of comparisons between performances of the children in the individual syllable tasks. They give a very clear picture of the overall results in the syllable tests and show particularly the impact of the picture syllable tests.

Figure 9.2.5 Time Group Interactions in both Oral and Picture Syllable tasks*



(c) Analysis of the effects of all the Phonological Awareness Tasks in the pre and post-tests.

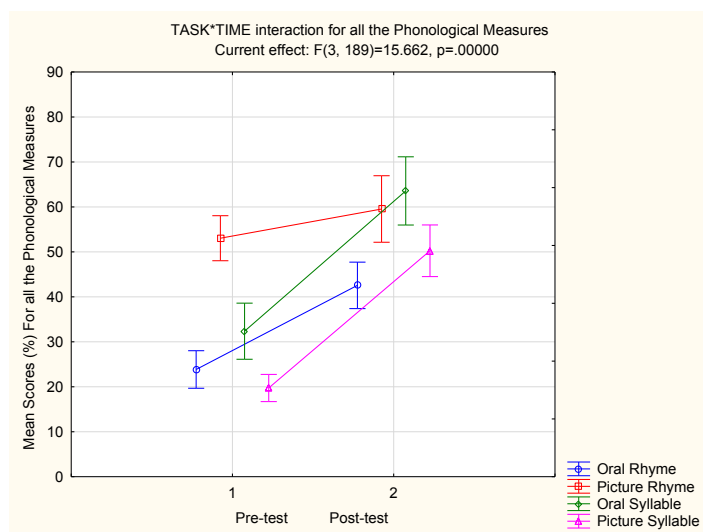
To get a more general picture of the effectiveness of the complete intervention programme a 3 x 4 x 2 (Group; Task: Oral Rhyme, Picture Rhyme, Oral Syllable, Picture Syllable x Time: pre and post-test) repeated measures ANOVA was computed.

There was not a significant main effect of Group ($F(2,63) = 2.7, p = .08$). However, as expected from analysis of the previous data, there was a highly significant difference for the main effect of task ($F(3,189) = 40.1, p = .0001$).

There was a significant interaction between Group and Task ($F(6,189) = 2.7, p = .02$). and a highly significant interaction between Task and Time ($F(3, 189) = 15.7, p = .0001$).

A visual representation of this is shown in Figure 9.2.6. It shows clearly that the children made least progress in the Picture Rhyme task, but they started this task with the highest level of ability.

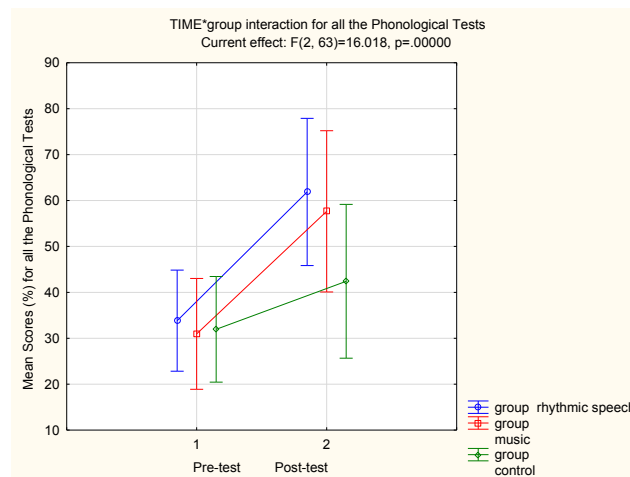
Figure 9.2.6
*Task*Time*
Interaction in the
Phonological
Measures



There were also highly significant differences for the main effect of Time ($F(1,63) = 234.3, p = 0.0001$) showing that elements in the interventions had been successful.

There was a significant difference in the interaction between Time *group in the pre and post-test analysis ($F(2,63) = 16.02, p = .0001$). Newman Keuls post hoc analysis shows that there were no significant differences at the pre-test stage, but at post-test although there were no significant differences between the speech and music groups there were significant differences between both speech and music groups and the control group ($p < .0001$ and $p < .001$ respectively).

Figure 9.2.7
*Time*Group*
Interaction in all
the Phonological
Tasks



A graphic representation is shown in Figure 9.2.7. It shows clearly that both intervention groups outperformed the control, but there was no significant difference between the performance of the speech and music groups.

A final Analysis of the Interaction between Group, Task, Time showed that the Phonological Measure that had made the most improvement and differentiated between the groups was the Picture Syllable Task. There were no significant differences between the rhythmic speech and music groups, but a highly significant difference between the rhythmic speech group and control ($p = < .0005$), and between the Music Group and Control ($p < .01$). This was the only task that showed significance.

These results show that an intervention based on either rhythmic structure in either a rhythmic speech form or in musical form can be successful in improving children's phonological awareness skills. The most significant message that comes from these results is that the rhythmic speech programme was a more successful vehicle than the music to improve the phonological skills of this group of 90 participating children. Both interventions were successful in improving both rhyme and syllable awareness, but the greatest improvements came in the syllable tests.

9.3. *Impact of intervention on concurrent reading skills*

In the analysis of Study 2 data there was little evidence of correlations between the whole group of participants and future reading skills so a partial correlation, controlling for IQ, was undertaken to see if individual groups rather than the whole group might show differences. The BAS reading test was taken 3 months after the intervention had been completed.

The group correlations (Table 9.3.1) show that the intervention groups show a greater correlation with future success in reading. The control group showed only one significant relationship between performance in the Picture Rhyme task and reading ($r = .423^*$, $p = .028$). The Music Group showed a significant relationship with the Picture Rhyme test ($r = .461$, $p = .013$) and a significant relationship with the picture syllable task ($r = .423$, $p = .022$). The Rhythmic Speech group showed a highly significant relationship with Oral Rhyme ($r = .608$, $p = .001$) and Picture Rhyme ($r = .488$, $p = .008$). There was also a significant relationship with the Oral Syllable task ($r = .451$, $p = .018$).

This would suggest that the rhythmic nature of both the intervention strategies does aid future reading skills.

Table 9.3.1. Pearson's Partial Correlations between Phonological Awareness Post test results and reading, controlling for I.Q for the matched groups

Reading (BAS)	Oral Rhyme	Picture Rhyme	Oral Syllable	Picture Syllable
Rhythmic Speech	0.608**	0.488**	0.451*	0.297
Music	0.154	0.461*	0.296	0.423*
Control	0.330	0.423*	0.272	0.186

* $p < .05$, ** $p < .01$.

9.4 *The analysis of further music tests on group performance*

Both the speech and music group were given poems and songs as part of the training programme. Irrespective of whether they were sung or recited they were delivered at the 500ms rate. Post-tests were therefore given to the groups to see whether performance had improved at this rate after the intervention. Because the children had found entrainment at 1000ms most difficult this rate

was also post-tested as a control rate. The rates of 400ms and 666ms were not post-tested because of a limited time allocation given to the research by the schools. Two further pieces of music were composed as post-tests with exactly the same musical criteria as before with respect to range of pitch, harmony and instrumentation. (Table 9.4.2) The metronome tests at 500 and 1000ms rates were repeated. The results are shown in table 9.4.1.

Table 9.4.1 Matched Group Drumming Pre and Post-test mean scores

Rate	Group	Pre-test Mean (SD)	Post-test Mean(SD)	Change a minus score shows improvement
500 ms Metronome	Rhythmic Speech	92.9 (22.2)	87.8 (38.5)	-5.1
	Music	107.6 (36.9)	102.3 (37.9)	-5.3
500ms Music	Rhythmic Speech	68.0 (27.3)	55.2 (17.2)	-12.8
	Music	84.2 (26.8)	67.0 (29.1)	-17.2
1000ms Metronome	Rhythmic Speech	197.9 (84.7)	203.4 (74.3)	+5.5
	Music	200.7 (27.1)	191.8 (79.4)	-8.9
1000ms Music	Rhythmic Speech	146.4 (34.8)	174.0 (52.6)	+28
	Music	175.5 (57.4)	177.7 (42.2)	+2.2

Table 9.4.2.

Schematic overview of the different music and songs used in the Post-tests

Task	500 ms	1000 ms
Metronome	“	“
Music for Beat Alignment	Tracy	Bear

At first glance the results in Table 9.4.1 indicate that the music-based intervention seemed to be more successful in improving drumming performance in all tests in comparison with the speech based intervention. However to explore the effects of both the rhythmic interventions more carefully a $2 \times 2 \times 2 \times 2$ (Group: Rhythmic Speech, Music; Rate: 500ms, 1000ms; Task: metronome, music; Time: Pre and Post-Test) repeated measures ANOVA was computed.

There were no statistical differences for the main effect of Group ($F(1,58) = 1.5, p = .23$) indicating that the programmes were equally effective in both conditions, and the interaction between Rate and Group also confirmed this, because there were no statistical differences between the performance of the groups at the different rates ($F(1,58) = 1.6, p = .22$). As expected there was a highly significant main effect of rate ($F(1,58) = 460, p = .00001$) as the children performed the tasks at 500ms much more efficiently than at 1000ms. This was confirmed by the interaction of Rate and Time which also showed significance ($F(1, 58) = 4.17, p = .05$). Newman Keuls post hoc tests however showed no significant differences between the performance of the children at the two rates between pre and post-testing but simply that they performed differently at the two different rates:- their scores at 500ms were lower than those at 1000ms.

There was a highly significant main effect of Task ($F(1,58) = 27.3, p = .0001$) suggesting that the children were much more successful in drumming to music than to the metronome. However the interaction between Rate and Task was not statistically significant ($F(1,58) = .063, p = .8$) because the children actually performed both the music and metronome tasks at the different rates in a similar way. The interaction between Task and Time also showed no significant improvements of the participants in either the music or metronome tasks ($F(1,58) = .002, p = 1.0$) between pre and post-testing.

It had been anticipated that there would be a significant difference in the children's performance in both groups after post-testing. This did not occur. There was no significant main effect of Time ($F(1,58) = .02, p = .9$). Nor was there a significant interaction between Time and Group ($F(1,58) = .56, p = .46$). This would suggest that the short intervention period made little

impact on the ability of the children as a whole to improve their drumming skills.

There were no significant interactions between Task and Group ($F(1.58) = 1.3, p = .26$). Neither were there any other statistically significant results found in the other 2 or 3- way interactions.

Both Interventions were based around training presented at the 500ms rate. Both the Rhythmic speech and Music Groups made gains at this rate, but they were not statistically significant. Where there was no additional training in drumming to the metronome the results between pre- and post-test remained quite stable at the 1000ms rates. This suggests, as stated, that to change young children's ability to tap accurately even at the more familiar rate of 500ms needs considerable practice. Perhaps the lack of additional access to musical training in the rhythmic speech group contributed to the decline in their performance at 1000ms, but once again this decline was not statistically significant. It is more likely; given the difficulties the children have shown in performing both drumming to music and the metronome, that this rate is intrinsically unstable and the score at the pre-test in the rhythmic speech group was the more unusual. The other 3 scores in this task are very stable.

Hence these results show that access to increased musical experiences do not necessarily increase the children's tapping ability. Rhythmic speech at the same rates can contribute equally well to improved tapping. However if music is the stimulus that is used within a classroom then a full musical experience will make a greater impact than simply tapping along to a metronome.

Low levels of literacy are a problem among children and adults in England, prompting both government agencies and researchers to test interventions and strategies that may be effective in promoting literacy (Rose 2006). Within early childhood, phonological awareness is a fundamental aspect of emerging literacy. Without an ability to comprehend and manipulate the sounds of the language it is very difficult to decode sounds into letters and then join them into words and eventually learn to read. One set of possible strategies to promote phonological awareness, and therefore reading, may include music-based interventions because both music and speech unfold in time, and rhythm is central to the sequential organisation of sounds in both domains. Before establishing such interventions it is necessary to establish the relationships between music perception and phonological awareness, and to find the key perceptual areas that link the two domains together. Once these are established then meaningful intervention in classrooms can take place, or beneficial remediation programmes for children with specific language impairments, such as dyslexia can be devised.

The purpose of this study was to look for these key areas by testing 192 4 to 5 year-old children, and developing a three group intervention strategy with 90 of these children that could shed light onto the rhythmic skills in music that linked to the essential phonological awareness skills involved in decoding syllables and rhymes.

Although, as a musician working with young children for many years, I had an innate bias towards developing a music programme that could bring increased awareness to early literacy skills, this research has led me to be circumspect about some of the key areas of music that might actually help increase phonological awareness. The inclusion of a rhythmic speech intervention, which used poems and jingles spoken in a chant-like way, but still maintaining an accurate rhythmic quality and pulse, and the success of this intervention in increasing understanding of syllables and rhymes means one has to question whether some of the preceding music intervention strategies have actually been causal in improving literacy. A major source of debate in the

music-language field is whether musical activity supports reading directly, or contributes to more generally applicable learning skills that make reading acquisition easier (Schellenberg, 2005). Classroom based research, such as this, where so many factors are beyond the control of the researcher, are often difficult, and yet this is the environment in which teachers and children work. While laboratory research might seem preferable to school-based research because of better control of confounding factors, laboratories are not where children normally experience music. However by using a variety of statistical analyses tools and by carefully controlling the factors within the research protocol and by concentrating on relevant musical ‘subskills’ with a large group of participants I hope to have provided ‘robust’ data to support and develop the hypotheses under scrutiny.

The question raised by the research and discussed in this chapter is which of the musical ‘subskills’ or elements can be easily introduced into an early year’s classroom curriculum and then most contribute to improved phonological skills? Given the nature of some of our early years’ teacher’s reluctance to sing is it possible that a programme of rhythmic chants could be equally beneficial, even though they have, perhaps, fewer attractive elements that make music so much fun and engaging for children and adults, such as pitch, harmony and timbre? If this is the case it is in line with Cummin’s (2010) hypothesis that rhythm in speech and rhythm in music are related via embodiment and entrainment and a programme that uses either or both, or rhythmic body movements could have beneficial effects on decoding rhythmic events in speech. Lidji et al (2011) working with groups of both English and French speaking adults compared the results of tapping to a song, rhythmic speech or normal speech to answer the question whether participants would entrain similarly in music and speech. Their hypothesis, in line with Large and Palmer (2002), was that although it is possible to entrain to temporal regularities that are present in speech it is much easier to entrain to an isochronous beat such as that found in a song or rhythmic speech. They termed the condition that I have chosen to call rhythmic speech as ‘*spoken regularly*’ (alignment of syllables to beat). Their results were, as I would have expected. It was much easier to entrain to both songs and speech spoken regularly than normal speech. They also found that synchronisation was more accurate when linked to music than rhythmic speech.

The tempo they chose for the tapping pulse rate was 120 bpm or an IOI of 500ms - the same one chosen in the interventions reported here. They asked the same significant question:- is melodic information necessary for entrainment, and their research concluded that it was not. This had been previously confirmed by the research of Snyder and Krumhansl (2001) who showed that when you remove pitch from a series of ragtime pieces it is still possible to entrain to the rhythmic structure that is left without impairment to synchronisation. Lidji et al maintained that their study was perhaps the first to ask the question whether rhythmic speech could be equally important for entrainment than music. This study is therefore probably the first to ask this question with small children and relate the results to improved phonological awareness.

10.1 Research Question 1

- Is there an optimum pulse rate within music that helps children to entrain to a beat and is it dependent on quality and type of stimuli?

This research has found that certain speeds are much more critical than others for entrainment to a beat and that there is a relationship between the ability to entrain to a specific pulse rate and acquisition of phonological skills. This confounds, to a certain extent, previous research that found no relationships between musical tempo discrimination and reading skills. Overy et al. (2003) performed tempo discrimination and tempo production tests on their group of 27 seven- to eleven-year-old boys of varying reading ability. Overy's tempo discrimination test involved asking the child to judge whether the second of two groups of computer-produced taps was faster or slower than the first. In her tempo production test, a computer presented eight taps at a steady beat over headphones, and the child copied the speed as accurately as possible on the keyboard after hearing the stimulus. The computer compared the inter-onset-intervals of the children's tapping in terms of deviation from the stimulus intervals, and the child was assigned a score based on the amount of deviation. The researchers did not find any significant correlations between these tempo tests and the children's performance in single word reading and spelling

measures. In effect this test asked the children to entrain to a beat without the stimulus – or as described here and by Thomson (2008) as ‘in the unpaced condition’. The children in this study found this very difficult, and were much more able to tap in time with music or a metronome when it was actually playing.

Also using a similar test design to that used by Overy et al.’s (2003), Montague (2002) tested her group of 23 eight-year-olds on tempo discrimination and tempo production tasks. On the tempo production task, the child’s recorded response was manually matched to a metronomic beat and a score assigned based on how well the child sustained or deviated from the given tempo. Montague did not find any significant correlations to phonological awareness tests in phoneme elision or blending phonemes nor did she find significant correlations between tempo production and phonemic decoding efficiency and word reading efficiency.

The problem of asking the right question to the right groups of children, and comparing like with like is yet again exemplified in the comparison with these studies and the research reported here. In this study I was working with much younger children, and looking for key elements of phonological skills that precede the understanding of phoneme deletion.

This research shows that tempo discrimination is a key factor in the acquisition of phonological skills.

10.1.1 An Analysis of the children’s Metrical Perception

The first research question required examination of the role of rhythmic accuracy and synchronization to a beat in music to find if there was an optimum pulse rate within the music that helped the children to entrain to that beat and whether that optimum pulse rate was linked to processing phonological awareness skills such as syllable and rhyme awareness. A subsequent question to the first was to explore whether good synchronization was linked to the actual sound source. Was it possible that many aspects that make music ‘music’ such as pitch, harmony, instrumentation etc... still contributed to determining rhythmic accuracy, over and above the rhythmic structure determined by meter and pulse? To discover this, a novel testing protocol was designed to

discriminate between different kinds of music and sound sources – some were complex with different instrumentation and multi layered musical effects, and some had simpler acoustic properties, such as a simple metronome sound or a single voice. The children were tested for their ability to synchronise to the beat at 4 pulse rates. Pulse rates at IOIs of 400, 500, 666 and 1000ms were used. These rates were considered because they were within the range of the ‘greatest pulse salience’ (Thaut 2008) and gave a wide range of pulse rates that were suitable for children to hear and move rhythmically to a beat (Honing (2012). Three of the rates (400, 500 and 666ms) had also been used in research into the rhythmic perception of children with developmental dyslexia (Thomson (2008) and in children with Specific language Impairment (Corriveau and Goswami, 2009)

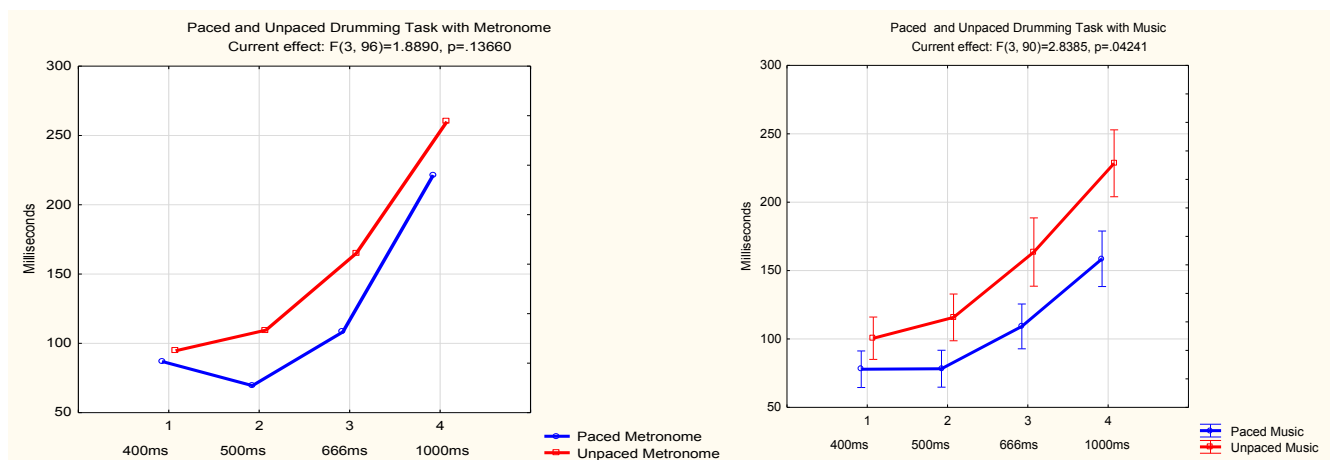
In Study 1 I looked at the ability of the children to drum in time with the music and metronome when it was playing (the ‘paced’ condition) and also to see whether they had an ability to maintain that entrainment to the beat when the music had stopped (the ‘unpaced’ condition). To further investigate this I also analysed the children’s responses to two contrasting sets of music to see whether the stimuli affected the children’s performance. The pieces were at exactly the same pulse rate but contrasted in terms of harmonization, timbre and musical milieu (See Table 10.1.1).

In the results comparing the different musical stimuli in both the paced and unpaced condition there was only one statistical difference between the children’s accuracy of response when tapping to the music. For the paced music task at the 666ms rate there was a statistical difference in the children’s response to the different sets of music. This could be because the Soldier’s Song was in duple time and the Ladybird song was in simple triple time (6/8). The disparity in performance would be in line with proponents of the ‘dynamic attending theory’ which says that both children and adults have a preference for regularly accented duple meters, rather than ones that have a strong weak, weak form. (Drake 1993, Drake et al., 2000; Jones & Boltz, 1989).

<i>Table 10.1.1 Music Composed for this study by Genre</i>				
	IOI	Title	Genre	Metre
Melodies used in the pre-tests	400ms	Music Day	Children's	duple
	400ms	The Race Song	Rock	duple
	500ms	Marching through the Jungle	March	duple
	500ms	Rover Had a Rag	Children's	duple
	666ms	Sputnic Song	Complex Si-Fi	duple
	666ms	The Soldier's Song	March	duple
	666ms	Ladybird	Relaxing (Children and Adults)	duple (compound)
	1000ms	Snake	(Children and Adults)	duple
	1000ms	Kite	Children's	duple (compound)
Melodies used in the post-tests	500ms	Tracy watches Tennis	Children's	duple
	1000ms	The Bear in the wood	Children's	duple
Additional material used in music intervention	500ms	Mickey The Mouse	Children's	duple
	500ms	Rocky the Rabbit	Rock	duple

The group responded most accurately to the song in duple time – the march. The music on all other tests did not make a difference to the accuracy of the children's performance. Differences seemed to be based on the pulse rate. The analysis showed that for this age range children find it very difficult to maintain a beat when there was no stimulus to listen to at all rates.

Figures 10.1.1 General trends in the paced and 'unpaced' drumming tasks in Phase 1



This is in line with the findings of Thomson in her cohort of 10 year-old normally developing and dyslexic children. Visual representations of the performance of the children in the paced and unpaced conditions are shown in Figure 10.1.1. They clearly show that the children drummed with greater accuracy to the music, rather than the metronome, and had a preference for drumming at the quicker rates of 400 and 500ms, but the most consistent rate in both conditions was at the 500ms rate when there was only a difference of 5 milliseconds between both conditions.

The fact that the children found tapping in the unpaced condition so difficult perhaps is a reason why Overy and Montague found no correlations between their music task and the results in their literacy and reading tests even though the children were older.

Because I had found no statistical differences between the two studies in their entrainment tasks I then looked at the full study to see the trends within the children's scores.

The results of the analysis of the data collected from the Full Study is given in appendix H.

In all cases, irrespective of stimuli, metronome or music, the children always performed with least accuracy when drumming to the 1000ms rate. This is not unsurprising since it is at the far end of the greatest pulse salience, and young children prefer a faster spontaneous tempo speed when tapping. The research of McCauley (2006) confirms that the rate of spontaneous tapping varies across ages. Young children will naturally tap at quick rates between 300 and 400ms IOI, and as we get older the rate becomes slower. In older children and adults the range for preferred tapping centres around the 600ms rate.

It was important to cross reference methods of analysis to gain an accurate measure of the children's entrainment to these various pulse rates whilst the children were drumming to either metronome or music and so three different analyses were employed to scrutinise the data from the whole study of 192 children.

The first used a linear statistical method, as used in the Overy and Montague research, where the children's ability to synchronise to a beat was

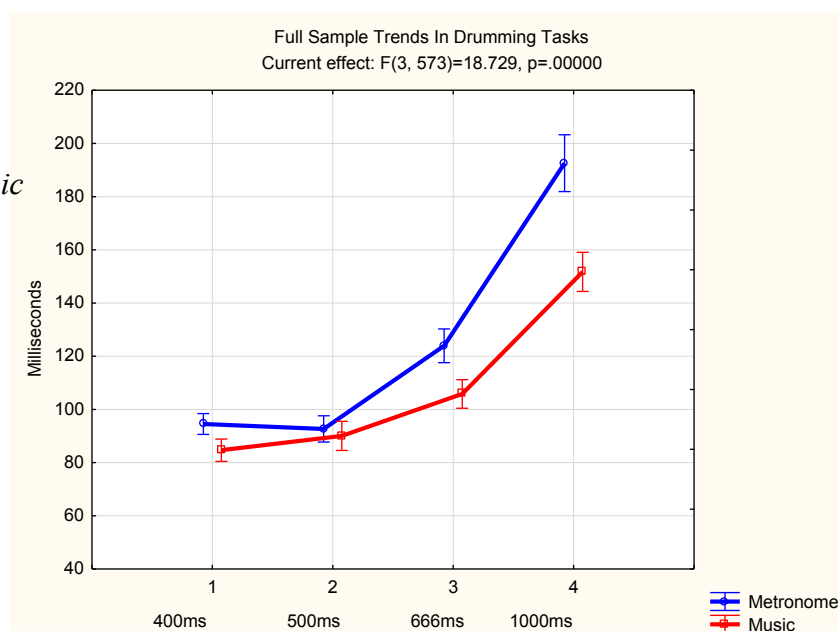
measured and analysed initially to find the error between exact synchronisation and their performance, irrespective of whether they anticipated or delayed their responses ('gross error'). The second method re-analysed the data taking into account the anticipated or delayed response. The third method re-examined the data used in the second method, but used a circular statistical analysis tool. This last method could only view the effects of the children's performance in the drumming entrainment tasks where there were 16 beats in each trial from which to track synchronisation across a 'phase', or in musical terminology across 4 bars of music set to an isochronous beat.

For the singing measures there were insufficient beats to analyse using a circular statistical analysis, so all these analyses are linear and based on the amount of deviation from the pulse that occurs when the child sings either before or after the beat.

a) Accuracy of metrical perception in the drumming tasks in the Full Study

Using the first method I found that children showed greater temporal accuracy (rhythmic entrainment) in keeping time with a musical piece than in keeping time with a metronome. The analysis showed a statistical difference in the main effect of task between the children's performance in the music and metronome tasks ($p = .001$) (See appendix H). A visual representation is shown in Figure 10.1.2.

Figure 10.1.2
Drumming to music
and metronome
Full study results



However for the metronome task, they were equally accurate in keeping the beat at the two faster speeds (400 ms, 500 ms), and were significantly more accurate at these two speeds than at either 666 ms or 1000 ms ($p's < .001$). This is in line with the research that shows children will respond most closely to their preferred spontaneous tapping speed. (Bobin-Begue (2005).

For the music task, they were also equally accurate at keeping the beat at 400 ms and at 500 ms, and they were significantly more accurate at these speeds than at either 666 ms or 1000 ms ($p's < .001$). Therefore the children's rhythmic entrainment was best at 400 ms and 500 ms. It was, however, only at the pulse rate of 500 ms that the children did not gain any significant benefit in terms of temporal accuracy from the musical accompaniment. (see Figure 10.1.3 and Table AH1 in appendix H).

There were quite similar findings in the second analysis that took into account anticipation and delay from the absolute point of synchronisation. The main difference was that in this analysis there was a near perfect alignment with the beat in the metronome task at the 400ms rate and a statistically different level of response at this rate between the metronome and music tasks ($p = 0.01$). The delay from synchronisation was only 1 millisecond (See table 7.2.1) and in the music task it was 16.8 milliseconds. This once again would be in line to the Bobin- Begue study. Drumming to a metronome, rather than to music has more in common with spontaneous tapping and is perhaps a purer form of entrainment. In line with the first analysis the difference between the music and metronome scores at the 500ms rate was marginally less than at the 400ms rate (14ms), but there was a greater margin of error from the point of synchronisation. At the slower rates of 666 and 1000ms there was no statistical difference in performance between the two rhythmic stimuli. (refer to Figure 7.2.1. for a visual representation). In line with the first analysis the children were most accurate at keeping the beat at 400ms and 500ms, and then they became increasingly inaccurate at the rates of 666ms and even more inaccurate at the speed of 1000ms.

The circular statistical analysis confirmed the findings of the first analysis in that the children were most accurate at the rate of 500ms in both the music and metronome tasks (See Table 7.2.3). It also confirmed the findings of the

second method that at the 400ms rate the children were more accurate when playing along to the metronome (See Figure 7.2.2).

The circular statistical analysis shows that the children delayed their responses at the quicker rates and anticipated their responses at the slower rates of 666ms and 1000ms. This is directly in line with the research into social drumming by Kirschner and Tomasello (2009) with similar aged children. They also discovered that the children did not drum in phase with the stimulus signal. Their research showed that when drumming along with a beat at 400 ms, most participants' synchronous tapping showed delays of approximately 10 to 120 ms. In this research these limits were found in both the children's responses to stimuli played at 400 and 500ms (1 – 23ms, after outliers had been removed). The findings from this research and Kirschner contrasts with the observation of a negative mean asynchrony in adults, where it has been found that the participants taps tend to anticipate the clicks of an isochronous sequence by approximately 20 to 80 ms (Aschersleben, 2002). However, in the 600-ms ISI condition, the older participants of 3.5 and 4.5 years tended to anticipate the stimulus beat by approximately 10 to 100 ms (similar to adults). They postulated that an explanation for this shift from positive to negative mean asynchrony could be that:-

“the participants needed to constantly push their “system of internal oscillations” (Large & Jones, 1999) toward the external driving rhythm at 600 ms ISI; this is also reflected by the median inter-response interval that rarely reached the ideal value of 600 ms. The combination of an imperfectly entrained oscillation system and a continuous error correction activity (Repp, 2005) that tries to compensate for the former would theoretically result in the observed tendency to precede the stimulus beat at 600 ms ISI but not at 400 ms ISI.” pg 312

When I looked at the results of all three analyses of the rhythmic entrainment data for drumming quite a clear picture emerges. When the children entrain to the beat at the rate of 500ms they are equally accurate when tapping to either stimuli. They entrain to the simpler metronome beat with greater accuracy at the rate of 400ms. In all analyses the children find entraining at the slower

speeds more difficult, but they seem to gain confidence from the metrical nature of the music whilst drumming at these more difficult pulse rates. This is also in line with the findings of Drake with reference to the children's ability to drum in time to the slow and complex rhythms in Ravels' Bolero (2000).

In general the results are in line with previous research that confirms that children and adults can entrain equally well to both a metronome and musical stimuli if it matches the speed at which they walk, or use gross motor skills. Styns et al (2007) examined how individuals walk to the sound of either a metronome or to music and they found that people could generally synchronize their movements whilst walking with either the music or the metronome at the 500ms rate. This is the also the rate at which most popular music is played, and encountered by children and adults (Moelants, 2002).

I can say with some confidence that there is a preferential pulse rate of 500ms but one cannot say conclusively from analysis of the data so far whether the children found the musical stimuli more attractive to entrain to than the metronome task, and which stimuli would best be used in a classroom to foster accurate entrainment and therefore improved phonological awareness. The raw data shows that more children participated in the music tasks than in the metronome tasks at the quicker speeds, but the differences were not significant. Further research would be necessary to provide a conclusive answer to this question, but at present it is not unreasonable to conclude that since listening, and playing along with music, is a more engaging activity carers would be more likely to engage with music that has a metrical and predictable structure than the simpler metronome sound (Patel, 2011). Drake (2003) also postulated that the children would respond most accurately to music from within their culture with a steady well defined beat, and Hannon and Trehub (2005) also reported that infants responses were greatest when the music they heard was familiar to them. If both the metronome and music played at 500ms give the children the greatest opportunity to entrain accurately, then it is sensible to use the stimuli that they preferred. Further analysis of the data when correlations were taken between the temporal measures and phonological awareness skills showed that there were more significant relationships between drumming to music and phonological awareness than when the relationships were tested between the PA skills and

drumming to the metronome. This gives further weight to using music within an early years classroom to improve phonological skills.

Without correlation with other cognitive or phonological measures one cannot say from this data whether the preference for the 500ms rate is a biological response, or one coming from increased exposure to music at this rate. Data confirming this hypothesis can be gleaned from the correlations between the entrainment tasks and phonological awareness discussed below.

b) Accuracy of metrical perception in the singing tasks in the Full Study (See appendix H)

In an early year's classroom environment the most often found musical activity is to sing, and more children were able to participate in the singing tests than in the tapping tests (173 mean complete scores for singing and 158 for tapping). Because song and speech are naturally related then investigations have focused on whether increased exposure to song might influence the children's phonological awareness (Schön, 2008). This theory maintains that the emotional aspects of a song could increase the level of arousal and attention, and the presence of pitch contours may enhance phonological discrimination, since syllable change is often accompanied by a change in pitch. However this research has found that although more children contributed responses to the singing tasks, and their ability to synchronise at different speeds was greater there was no consistent pulse rate that was linked to the phonological skills under review, and after correlation with the phonological measures I found less significant correlations than those found with the drumming tasks.

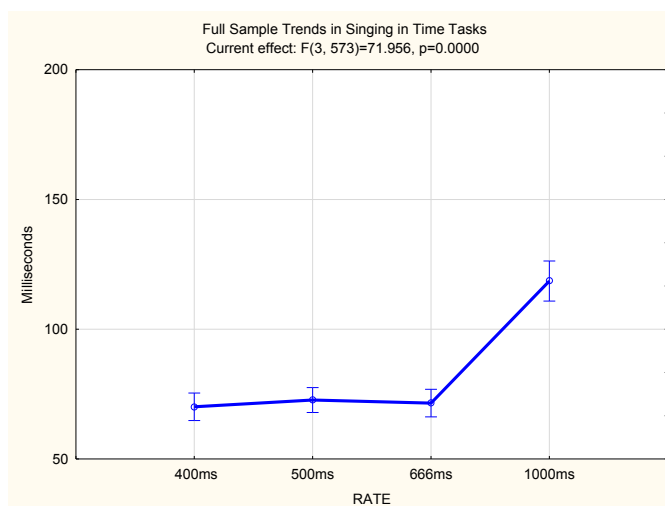
In a classroom sometimes children will sing along with the teacher's voice or to pre-recorded music and at other times their singing might be quite spontaneous. Depending on the activity one might want to sing a known song faster or slower, and the children in this study showed a remarkable capacity to sing known songs at different speeds with equal accuracy according to a simple instruction :- "Let's sing a hello song for a dinosaur" – or "Let's sing a hello song for a duck". Ducks move faster than dinosaurs so the song can go faster. Perhaps because the children had experience of singing songs at various pulse rates I found no preferential rate at which they sang more accurately than

another.

In the Singing in Time test which compared the children's responses to the Hello Song at 4 pulse rates I found in an analysis that scored the children's responses as a gross error from the beat that not only were the children more accurate at the rates of 400 ms and 500 ms, but they were also more accurate at the rate of 666 ms in comparison to the slowest rate (1000 ms). In Figure 10.1.3 we see a visual representation of this analysis.

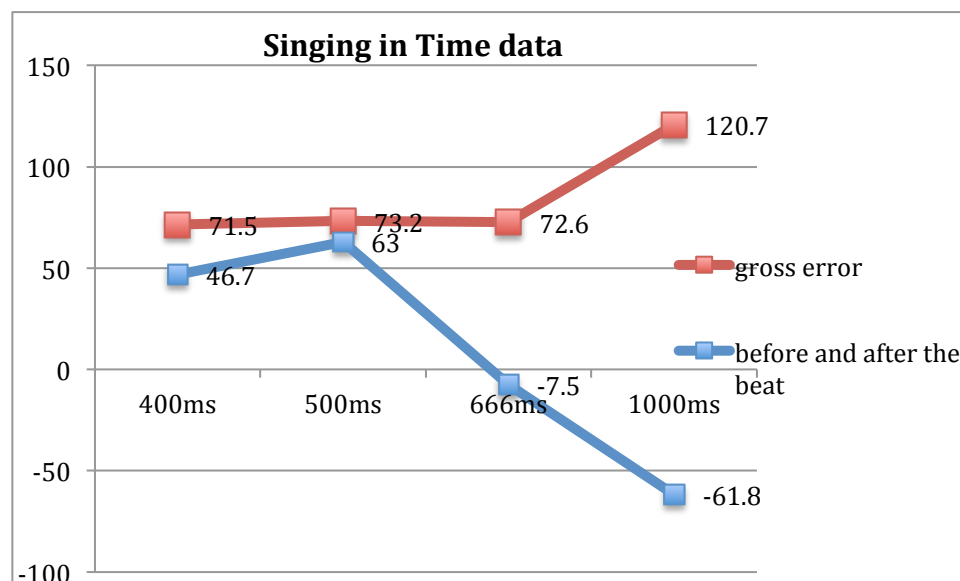
Figure 10.1.3

An analysis of the accuracy of singing, using 'gross error' synchronisation scores



In the second method of analysis, when the scores reflected whether the children anticipated or delayed their responses we see a different trend and this analysis showed greater differences between the various effects of pulse rate. (Figure 10.1.4) The children were most accurate at the 666ms rate with only a small deviation from the exact point of synchronisation (- 7.5 ms). In line with the effect we saw in the drumming tasks the children anticipated the beats at the slower rates, and delayed their responses at the quicker rates. Both analyses show that the children performed inaccurately at the 1000ms rate.

Figure 10.1.4
A comparison of
the Singing in
Time data –
comparing the
effect of a gross
error score with a
score that reflects
whether
synchronisation is
anticipated or
delayed.



Both the Singing in Time tasks and the drumming to music tasks involved playing or singing to a musical backing track, and I expected that if a general rhythmic embodiment is present in young children, then the accuracy of singing in time should be correlated with the accuracy of playing the Bongo drums in time, particularly if a musical accompaniment was present, supporting the rhythmic and metric structure. Relations between temporal accuracy in the rhythmic entrainment and singing tests were explored by computing partial correlations between the beat alignment with music task and the Singing in Time task, taking general cognitive ability (WPPSI) as the covariate. In the full study I found that the Singing in Time task was significantly correlated with I.Q. for the rates of 400 ms and 500 ms and the beat alignment with music task was significantly correlated with I.Q. for the 500 ms rate (See data in appendix H). The metronome task was not significantly correlated with I.Q. at any rate. There were many more significant correlations when the rhythmic entrainment task involved musical accompaniment than when the entrainment task did not involve music (the metronome measures). (See Table AH3)

Figure 10.1.4 shows that in the Singing in Time tests we get a more ambiguous picture in terms of a preferential rate. Using the gross error scores we see little difference in the children's performance at 400, 500 and 666ms rates. However in the second analysis we can see quite clearly that for the first

time in the entrainment analyses that the 500ms rate is more inaccurate than any other rate, even the 1000ms rate, with a delayed response time of 63ms.

In the Singing the Rhyme measures, which asked the children to sing along with either a musical accompaniment or just to a voice, the results once again showed that in the Full Study the 500 ms (2 Hz) rate was the temporal rate for which rhythmic accuracy was highest. There was a benefit from a + Music experience for the most accurate speed (500 ms), as keeping the beat was significantly better at this rate when the children were singing along to music than to a voice alone. (See table AH2). The Music also provided more support at the 666ms rate.

The scores from the Rhyme tasks were only taken on specific words or syllables. This is, arguably, a poorer measure of entrainment than the other protocols I used where I could measure a series of data points in each task (16 in the drumming tasks and 6 in the Singing in Time tasks). It is still, however, a measure of entrainment because the children need to anticipate where the missed word comes in the nursery rhyme from the previous series of rhythmic accents.

Overall, I found that even though singing is a good measure of rhythmic embodiment, when I looked at the correlations between the temporal accuracy in singing I found that it was not strongly related to phonological awareness. This to a certain extent was surprising since the data I have reviewed and collected shows developmental links between rise time perception, rhythmic entrainment and phonological awareness. It has shown the core importance of rhythmic entrainment to metrical structure (the succession of stressed syllables) for successful language acquisition by children. In singing the relationship between accented notes and syllables, particularly in children's songs, is very strong. Singing is a universal form of vocal expression and a social act, and we are beginning to find evidence that entrainment is improved by the social condition (Kirschner and Tomasello (2009). Further recent evidence from adult studies has shown strong links between poor rhythmic entrainment and poor singing so one can surmise that the opposite is true. Most occasional singers can sing in tune and in time (Dalla Bella et. al., 2007), and can successfully imitate tones and short melodies (Pfordresher & Brown, 2007). Yet, important individual

differences have been observed, with some individuals (i.e., poor singers) singing out of tune and/or out of time (e.g., Dalla Bella & Berkowska, 2009; Pfordresher & Brown, 2007). This research has concluded that variability among occasional singers is related to their ability to synchronize with a beat. The question of whether accurate pitching of the notes when singing improves beat perception is largely un-researched in children of this age when their vocal representation of pitch is so immature. In the Schön et al, research (2008) with 8 year-old children, they combined linguistic and musical information and compared language learning based on speech sequences to language learning based on sung sequences. Their results confirmed that song was a useful means for helping children segment new words. They could not however exclude the fact that the results favouring their musical intervention was not due to structural and motivational properties found in the music. It does appear that melodic patterns can contribute to a listener's sense of meter and that listeners also respond differentially to various combinations of melodic and temporal accents (Hannon, Snyder, Eerola, & Krumhansl, 2004; Jones & Pfordresher, 1997), especially if the relative salience of different accent types are well calibrated, as in the matching of lyrics and music (Ellis & Jones, 2009). However most present research implies that rhythmic information is significantly more important than melodic accents in predicting listeners' perception of meter (Hannon, Snyder, Eerola, & Krumhansl, 2004; Snyder & Krumhansl, 2001) and some researchers (Huron and Royal, 1996) have even questioned the effectiveness of melodic accents for marking meter, suggesting that melody and meter are perceptually independent.

10.2 Research Question 2

- Will accurate metrical perception predict improved phonological learning?

The second research question explores whether the speed at which the children were able to entrain to the beat, actually matched with their ability to process phonological awareness skills, such as identifying and manipulating syllables and rhymes. These comprised two tests of rhyme awareness, and two

tests of syllable awareness. As the children were very young, I used both picture-based tasks and oral tasks to measure their phonological awareness.

- Picture RhymeTask. This task was taken from James et al., 2005. Children were shown a cue picture and three alternative choice pictures. They were asked to select the alternative that rhymed with the cue picture (e.g., key, sea). There were 24 trials in total.
- Oral Rhyme Task. This was the Oral Rhyme Test from the PhAB (Phonological Awareness Battery, Fredrickson & Frith, 1997). Children were asked to identify which two of three words sounded the same at the end (e.g., sail, boot, nail). There were 21 trials in total.
- Picture Syllable Task. This task also came from James et al., 2005. Children were shown a cue picture and three alternative choice pictures. They were asked to select the alternative that had the same number of syllables as the cue picture (e.g., torch: nurse, camel, tiger). There were 27 trials in total.
- Oral SyllableTask. This task was adapted from Treiman and Zukowski (1996). Children were presented with pairs of words spoken by a puppet, and had to tell the experimenter whether the word pairs shared a syllable or not (e.g., compete, repeat). There were 40 trials in total.

In addition to these tasks the testing protocol used three measures of cognitive ability. Two tests were taken from WPPSI R^{uk}, (Information and Picture Completion) to test general intelligence. A further measure used the teacher's own assessment from The Foundation Stage Profile (Qualification and Curriculum Authority, 2008) and used the Communications, Language and Literacy subset to assess the children's general understanding of pre-literacy skills. The third test was a Word Recall Test from the 'Working Memory Test Battery for Children (Pickering and Gathercole 2001).

In the results chapter we saw that the performance of the children in Studies 1 and 2 were well matched in both cognitive and P.A. measures but the results of the tests were sometimes at variance with each other, so it was important to look at the results from the full study.

Performance in all four of the phonological awareness tasks was

significantly correlated with I.Q. (WPPSI) so I.Q. was controlled using partial correlations. I expected to find relations between temporal accuracy and phonological awareness in both the syllable and rhyme tasks, since accents mark the syllable onset or more specifically the perceptual centre (the ‘p’ centre), and this is also a cue to the onset-rime division of the syllable, that therefore would aid perception of rhyme placement in either a song or the speech stream. The results showed that this expectation was in place, but by far the strongest relationships were found in the entrainment measures to drumming with a musical accompaniment rather than drumming to the metronome or in the singing tasks.

Relations for the rhythmic entrainment tasks with the drumming tasks are shown in Table AH 4 and relations for the singing tasks (Singing in Time, Singing the Rhyme with and without musical accompaniment) are shown in Table AH5 in appendix H.

Inspection of the results from the correlations between phonological awareness and drumming revealed only one significant relationship for the metronome task. Drumming at the 400 ms rate was significantly related to performance in the oral syllable task. However for the drumming to music task, both the 500ms and 666ms rates showed significant correlations with phonological awareness. For the 500ms rate the significant correlations were with oral rhyme awareness, picture rhyme awareness, and oral syllable awareness. For the 666ms rate there was a highly significant relationship with the picture rhyme awareness task. The results show that for different measures of rhythmic entrainment (to a metronome or to music), all the rates of greatest pulse salience (400ms, 500 ms and 666ms showed some significant correlations with oral language processing (phonological awareness of rhymes and syllables). For the Singing the Rhyme measure, the 400 ms rate in the +Music task was significantly correlated with picture rhyme, and with picture syllable. In the Singing the Rhyme measure – Music task there was one significant correlation between drumming at 666ms and the Picture Rhyme test.

The most consistent relationships between rhythmic entrainment and phonological awareness occurred for drumming to music at 500 ms (3 out of 4

correlations significant, and the correlation with the picture syllable task just missed significance). So in this research I found that individual differences in the temporal accuracy of entrainment by young children do show some significant connections with their phonological awareness and the first research question could be answered in the affirmative.

10.3 *Research Question 3*

- Are there auditory and temporal processes that are used in perceiving both music and language?

The answer to this question is ‘yes’. However we need to qualify that to a certain extent because the research and information flow on the topic is very new and many are dependent on findings from small sample studies of the brain where researchers have searched for activity that involved auditory processing in both language and music. There are as yet very few large participant studies with young children that can apply the findings of the brain-based research into educational practice. This study has been designed to add knowledge to this area of research.

Increasing neuro-scientific evidence shows that the brain has the ability to adapt to changing circumstances. It has ‘plasticity’.⁴² The implications for this are that with ‘training’ the brain can both re-distribute resources to areas of the brain that have lost function, or increase the capacity of some areas of the brain to facilitate enriched performance.

The importance of music as a tool for change is exemplified in the work with brain damaged patients who have lost the capacity to speak.

Research has shown that the brain can adapt after stroke or serious injury. Patients suffering from ‘aphasia’ where they have lost the ability to produce or

⁴² **Neuroplasticity** (from neural - pertaining to the nerves and/or brain and plastic - moldable or changeable in structure) refers to changes in neural pathways and synapses which are due to changes in behaviour, environment and neural processes, as well as changes resulting from bodily injury. Neuroplasticity has replaced the formerly-held position that the brain is a physiologically static organ, and explores how - and in which ways - the brain changes throughout life.

comprehend language have been helped to speak again after intensive ‘Melodic Intonation Therapy’ (Schlaug et al 2008). Where the brain has been damaged after a trauma in the left hemisphere, where language skills are generally found the MIT therapy has been responsible for recruiting speech production regions in the right hemisphere in order to facilitate the recovery process. The MIT therapy uses a melodic contour that follows the prosody of speech and rhythmic tapping of the left hand accompanies the production of each syllable and serves to improve fluency. After intense treatment, patients who were totally incapable of saying their own name or reciting the words of “Happy Birthday” could do both. During the therapy, the patients practised singing phrases and then slowly brought the musical contours into more acceptable speech prosody. The effects were long lasting. (Schlaug et al 2009).

If the childhood brain can adapt to training then this is of particular importance in helping children with difficulties in perceiving and decoding their language to perform with greater efficiency. It means, fundamentally, that appropriate interventions can be effective because we know that the childhood brain is able to re-organise itself in response to circumstances and stimuli and performance in cognitive function can change.

Schellenberg, (2005) and Schellenberg & Peretz, (2008) investigated whether there were any causal links between enhancement of IQ and instrumental music lessons. In 2004 Schellenberg had concluded that there did seem to be some transfer but he still raised doubts about the possible causes of the transfer because he considered that there might be many other contributory factors connected to experiencing music lessons that could equally well have increased the children’s IQ scores, such as the very fact that they had increased learning opportunities, or that it was enjoyable, and significantly that they might have had more latent ability. These concerns were repeated in a 2008 article (Schellenberg, 2008) concerning the impact of music on IQ. However in more recent research (Moreno & Schellenberg et al, 2011) it was suggested that a more focused short computer based musical training programme could improve verbal intelligence and show causality. The children’s cognitive and musical ability was matched carefully prior to the intervention and the training with the 6 year-old children was based on a combination of motor, perceptual, and cognitive tasks that included training in rhythm, pitch, melody, voice, and basic

musical concepts. This training relied primarily on listening activities. Their results showed that over 90% of the music-group participants improved their verbal intelligence.

10.4 Research Question 4

- Can auditory and temporal processes enable the extraction of periodic structure and rhythm, and can one assume that individual differences in the quality of these basic auditory processes affect the development of language and musical cognition?

In the literature review I looked at the very origins of speech and language and found that there is now a wealth of neuro-scientific research showing that the two are inextricably linked in the oldest part of the human brain – the brain-stem. Both Grahn, (2007) and Strait and Kraus (2012), amongst others, suggest that the brain-stem processes the temporal rhythms that help the brain to extract and process information from the auditory cortex that is then used to extract information that can be turned into speech or the motor skills that drive rhythmic reactions to music. And it is in this area of temporal and rhythmic processing that we can see the closest and most relevant links between the ability of the brain to process the acoustic signals that lead the child to discriminate the onsets in the speech stream, and the accents that generate meter in music.

The study of neural (brain) plasticity involving music and language was one of the first areas explored by neuroscience because it was thought that because both involved analytic listening and shared mechanisms and underlying brain structures (Patel 2010) it was reasonable to suggest that when there were functions that were common to both areas, such as compatible processing speeds in music and phonological awareness skills then transfer could occur between the two domains. The corollary of this is that when there are deficits in both speech and music, and they originate in the same processing mechanisms in the brain then improvement in one might lead to improvement in the other.

Goswami (2002, 2010) has shown that one such common area involves decoding signals associated with amplitude envelope patterns because decoding

of subtle changes in accent within the amplitude envelope is an important feature in both speech and music perception. In speech, the amplitude envelope plays an important role, because within it we find cues to speech rhythm (e.g., stress) and syllable boundaries, which in turn help listeners segment words from the flow of speech (Cutler, 1994). The amplitude envelope is also an important acoustic feature of musical sounds. Research has shown that the amplitude envelope is one of the major contributors to a sound's musical timbre (e.g., Caclin et al., 2005). Changes in the structure of the envelope allow a listener to distinguish between the sounds of a bell or a violin. Rise-time is also involved in the amplitude envelope at tone onset in music and is an important cue to the perceptual attack time of musical notes, and thus to the perception of rhythm and timing in sequences of musical events (Gordon, 1987). Patel (2011) proposes in his OPERA hypothesis that since the envelope is an important acoustic feature in both speech and music then:-

“musical training which relies on high-precision envelope processing could benefit the neural processing of speech envelopes, via mechanisms of adaptive neural plasticity” pg 10

Studies of early phonological development in English suggest that infants and very young children learn to listen for the stress or accents as part of the phonological representation of a particular word (e.g., Farmer and Klein, 1995). Many English words used with infants and young children follow a strong–weak pattern (mummy, daddy, baby, doggie), and so it is possible that familiarisation with these common stress patterns plays a role in the development of their knowledge of how words are constructed. In general, strong syllables are louder and longer than weak syllables, and have a higher pitch frequency. Sensitivity to the predominant stress patterns of English words is clearly important for segmenting words and syllables from the speech stream, and therefore for phonological representation (see also Echols, 1996; Mattys & Jusczyk, 2001).

Saffran (1999, 2003) identified that infants used similar mechanisms to track both linguistic and musical cues in order to comprehend the speech of their parents. The research proposed that an infant looks implicitly for statistical probabilities as she/he tries to differentiate and segment words within the speech

stream. If the infant hears the syllable 'pr', it is statistically likely to be followed by 'ti' (80% probability) in an infant /carer relationship. If the infant then hears 'bay' it is likely that the next syllable will be 'be' – making 'pretty baby'. The research showed that infants became more efficient at isolating the syllable groupings when these groupings were linked to a simple musical phrase.

More recent research by Kotz and Schwartz (2010) proposed that speech perception is inherently linked to rhythmic timing via the perception of rhythmically prominent syllables (stressed syllables). They argued that stressed syllables, cued by rise time, provide a rhythmic temporal structure that might be used by the brain in encoding and understanding speech. In other words these stressed cues are analogous to the accents found in music and they infer the perceptual beat or rhythm of a particular speaker's utterances. Both Kotz and Schwartz and Goswami argue that speech is inherently rhythmic and that the accents in speech (the P-centres linked to the onset of the vowel nuclei - rise times) help the brain to find the stressed syllables that are important events in the temporal structure of the speech signal, and that oscillatory mechanisms found in the Delta and Theta frequency bands are important in the neural encoding of this rhythmic temporal structure.

If human utterances are structured so that stress beats lie at privileged phases of a higher-level prosodic unit, for example marking word onsets or phrase-level information (Cummins & Port, 1998; Greenberg, 2006), then periodicity might be the key organisational principle underlying phonological structure in human speech. This is akin to the way we have seen that children are able to see the rhythmic musical patterns in 'chunks'. They can order their listening in phrases (Bamberger and Davidson) and are aware of when the phrase is coming to an end (Koelsch, 2003). The strong metrical qualities, based on accented patterns facilitate this.

On the basis of these theories I therefore expected there to be strong links between the ability of the children to entrain to strongly accented musical stimuli and their ability to recognise syllables and rhythms in the phonological awareness tests. If correlations occurred at specific pulse rates it would be indicative of entrainment and neural efficiency in decoding syllable-level events in the speech signal at those rates.

I found that children were accurate in their entrainment to drumming tasks at speech-relevant rates (400 ms, 500 ms and 666 ms – 2.5 Hz, 2 Hz and 1.5 Hz) and therefore it might be expected that they might also be more efficient at using the temporal structure within the speech signal for encoding and understanding speech (Kotz & Schwartz, 2010), and for developing high-quality phonological representations (Goswami, 2011). These rates fall within the Delta (1.5 – 4 Hz) frequency bands shown to be important in recent auditory neuroscience studies of speech encoding by the brain (see Hickok & Poeppel, 2007).

I also found that the most consistent rate throughout the correlations between the phonological measures and drumming was at 500 ms (2 Hz) (3 out of 4 correlations significant, and the correlation with the picture syllable task just missed significance). Stressed syllables occur approximately every 500 ms (2 Hz) across languages (Arvaniti, 2009), and other biological studies also converge on 500 ms as an important “resonant frequency” in human movement (MacDougall & Moore, 2005), particularly when humans are engaged with music (Moelants, 2002) or with rhythmic speaking (Fant & Kruckenburg, 1996), it was also suggested that 500 ms may be a developmentally important temporal rate for assessing relations between rhythmic entrainment, music and language.

If we are to use this rate and the knowledge that we have acquired about the plasticity of the brain and its ability to change and adapt we can gain greater confidence to apply the results found in the study and apply them in an intervention to help children with language and literacy difficulties.

Liberman (1975, 1977) originally proposed that speech, music and dance all conformed to the “metrical organisation hypothesis”, that all temporally-ordered human behaviour is metrically organised. If children find it difficult to respond to these strong rhythmic properties in music, or in rhythmic speech then we find that they do not progress from a fluency in language to a fluency in literacy.

Children with language-based learning impairments not only have difficulties in speech segmentation tasks (Evans et al. 2009) and an impoverished perception of speech rhythms (Abrams et al. 2009; Goswami et al.

2011), but also have a poorer performance than typically developing children in tasks involving musical metrical structures (Thomson, 2008, Huss, Verney et al . 2011, Goswami and Huss et al 2012). This strongly supports the view that musical training, by fostering rhythm perception and production, may have an important role for the development of language skills in children.

10.5 *Research question 5*

- If rhythmic structure and temporal isochrony is more overt in music than in language and enables the accurate segmentation of syllables and words from the speech stream, is it possible that musical interventions could improve reading skills in children with developmental language disorders. (Goswami 2011, Overy, 2000, 2003; Forgeard et al., 2008)?

The literature discussed suggests that rhythmic timing in language development is linked together with rhythmic timing in music within the amplitude envelopes that are processed by overlapping brain circuits. These conclusions have been researched within the area of developmental dyslexia, because of the obvious deficit these children have in learning to read. Even at the ages of 2 and 3 years, before testing for phonological awareness can usually take place, Smith et al (2008) reported speech timing difficulties in children who had a genetic risk of developing dyslexia. Comparisons with rhythmic beat perception or drumming to music have not been researched with this age range, but it might be a fruitful avenue for future research to track the emerging problems in both domains.

In my research with the 4 and 5 year-old school age children, even though the pulse rate of 500ms was linked to phonological awareness skills I found no correlations with the pulse rate of 500ms in the correlations between beat perception and reading. However this rate has proved extremely important in a series of experiments with dyslexic children who were older (10 years of age) in aligning reading skills to musical metrical perception.

In previous interventions that have included rhythmic entrainment as a tool to improve reading with dyslexic children (Overy, 2000, 2003; Forgeard et al.,

2008) some evidence has accrued to support the theory that training in music does support improved reading performance. Two recent studies with dyslexic children, rather than focusing on varying musical characteristics have focused on identifying a strong link between a deficit in processing rhythmic information at the specific pulse rate of 500ms and deficits in word reading. There is, therefore, a case to say that focused interventions in musical beat perception could be more helpful in improving phonological awareness and future reading skills than a more generic music intervention.

Alongside Martina Huss (2011 & 2012) I devised a quasi - musical metrical test to be used in addition to tests showing how the children responded to rise time (see Chapter 2.5). Initially this test was described as a ‘musical metric task, but since there is no change of pitch it is more accurate to describe it as a task to explore musical beat perception. The chosen pulse rate of 500ms was based on emerging evidence from the MEd pilot study I conducted in 2008 which had shown a strong relationship between this pulse rate and phonological awareness ability. Linguistic reviews of rhythmic processing had also shown that, across languages, stressed syllables occur on average every 500 ms (2 Hz, Arvaniti, 2009). The test used a natural sounding chime bar tone pitched at G (392 HZ). The sound files were created using Sibelius Version 4 from a sampled sound set produced by Native Instruments (Kontakt Gold) so the notes sounded musical with appropriate timbre and slow decay times. The children had to detect either short (100 ms) or long (166 ms). small delays in the rhythm structure within a two bar phrase. Each note that was delayed was also accented. In each task the children listened to two phrases and had to make a same-different judgement:- were the two “tunes” the same or different? Performance in the musical beat perception task along with age and IQ explained over 60% of the variance in concurrent single word reading in their sample of 64 children. The musical beat perception measure showed stronger associations with reading (predicting 42% of unique variance) than traditional phonological awareness measures (a rhyme awareness measure, which predicted only 33% of unique variance). The researchers concluded that the predictive strength of the musical beat perception measure arose in part because certain aspects of auditory processing are related to both musical perception and phonological awareness,

which is related to reading development (Anvari et al., 2002). In line with my findings sensitivity to pitch was not related to reading development, whereas sensitivity to rise time was.

This suggests that Huss et al.'s accented beat perception task was measuring something of perceptual importance to the development of phonological awareness and reading. As reading development is tied so closely to the development of phonological awareness, Huss et al. (2011) found that the accurate perception of metrical structure was likely to underlie both musical and phonological (prosodic) processing. These findings were replicated in a further test of the children one year later, giving increased weight to their hypothesis. In fact the dyslexic children performed with less accuracy than in the previous year supporting the theory that their deficit in beat perception was deeply seated. (Goswami and Huss, 2012).

In answer to the fifth question my research strongly supports the linkage between deficits in musical beat perception and reading. It also strongly suggests that the pulse rate of 500ms is critical not only for its linkage to phonological awareness skills, but it can act as a predictor for finding deficits in children with developmental dyslexia. Whether that beat-based programme should be musical, or perhaps include other significant motor skills that are linked to the pulse rate of 500ms is once again not specifically proven. A systematic investigation of the developmental effects of rhythmic co-ordination such as dancing or marching on speech and language outcomes is necessary. Research from sports psychology found that athletes can become more focused if they listen to music played at between 120 and 140 bpm prior to competing in an event. (Bishop et al., 2007). Within this domain research has consistently shown that the synchronization of music with repetitive exercise is associated with increased levels of work output. This applies to such activities as rowing, cycling, cross-country skiing, and running. Musical tempo can regulate movement and thus prolong performance. Synchronizing movements with music also enables athletes to perform more efficiently, again resulting in greater endurance. In one recent study, participants who cycled in time to music found that they required 7% less oxygen to do the same work as compared to cycling

with background (asynchronous) music (Bacon, Myers, & Karageorghis, 2012). The implication is that music provides temporal cues that have the potential to make athletes' energy use more efficient.

Research into the coordinated movement of young children is now possible, with the advent of accurate synchronisation methodology using computer generated image and sound integration techniques (Bruyn et al 2009) and may support the intuitions of some prominent educational theorists about the centrality of embodiment to cognitive development (Jacques Dalcroze, 1980; Kodály, 1974). The Bruyn study is interesting, because it mirrors the research by Kirschner and Tomasello, (2009) showing that synchronization in dance was also linked to a social condition. The children and adolescents performance improved when they danced with others.

My data in general provides support for the idea that the co-ordination of rhythm in voice and bodily motor movement could be related to phonological development, supporting Cummins' view that rhythm in speech and rhythm in music are related via embodiment and entrainment (Cummins, 2010). The data also suggest that such activities with young children could usefully be based at the 500 ms rate, but they do not suggest that this is the only developmentally valuable rate. However one can relate the findings of synchronisation and entrainment at 500ms to a non-musical activity – rhythmic speech.

10.6 Research Question 6

- Is it possible that the rhythmic attributes of rhythmic speech are as, or equally, effective in helping children to segment the speech stream and therefore gain greater understanding of the skills required to process phonological information, and in so doing become more able to decode the language in readiness for reading?

If the temporal sampling theory has validity then the only way to test the theory is via experimental studies where groups of individuals are matched at

the outset in terms of behavioural measures and musical ability, and then exposed to different amounts of musical or rhythmic training. If musical training improves phonological awareness abilities, then this would be strong evidence for shared neural resources. The key areas of discussion regarding the intervention programme is whether the music training programme helped the children to increase awareness of phonological skills. If it did then it would be in line with many previous studies. The second, and perhaps more important question is whether it outperformed the speech based intervention, that also used a comparable rhythmic teaching methodology.

The three groups, speech, music and control were selected on the basis of their WPPSI R^{uk} scores. 9 children were rejected from the study on the basis of either their very high or low scores. Three further tests scores from the psychometric pre-test data were compared to establish the comparative nature of the three groups. No statistical differences were found so the groups seemed to be well matched.

Further tests on the children's musical ability in drumming and singing were analysed. There were no differences in the ability of the groups to attempt the tasks, and only one statistical difference was found in their ability to drum or sing to the pulse rates at 400, 666 and 1000ms. Surprisingly, given the previous analysis of the data the children in the speech group performed with greater accuracy in the drumming and singing tasks at the 500ms rate. There were no statistical differences between the music and control groups (see Tables 9.4.1). The difference in accuracy at the 500ms rate between the intervention groups is not the important factor. What is significant is the stability of performance at this rate, especially in the metronome task. There was only a marginal improvement in both groups of 5ms between pre and post-testing, suggesting that the training did not impact on this underlying processing rate. In the control group the change between pre-and post-testing in the drumming to metronome task was only 1ms. In the 500ms drumming rate to music there was once again only a marginal improvement between groups. The music groups performance scores improved by 17ms and the speech group improved their scores in this task by 13 ms. In the control group the difference was only 10ms. This might suggest that any improvements were either purely by chance or perhaps by

maturation. The analysis confirmed that these improvements between groups were not significant.

In both the Pilot study and Phase 1 of the study the overall results in the musical entrainment tasks suggested that the most appropriate rate on which to base an intervention to improve phonological awareness would be the 500ms rate. The results outlined above confirm the stability of this rate. The intention of the study was never to improve performance in a musical sense but to improve the children's phonological skills, so the success of the training programmes was dependent on improved results in the phonological awareness tasks in the intervention groups.

The results showed that the intervention based on the rhythmic entrainment rate of 500ms was successful in improving the phonological scores in both training groups. In the rhyme tasks all groups, including the control group made similar improvements during the training period. The music group made a near significant improvement over the control. However the methodology employed favoured improvement in the syllable tasks rather than in the rhyme tasks. Both in music and rhythmic speech we can easily discern when a beat matches a syllable. The rhythmic nature of the intervention therefore favours this connectivity, and both intervention groups outperformed the control group.

The important outcome of the training programme was that both intervention groups made improvements over the control, but there was no statistical difference between these groups. This result therefore would suggest that it was the rhythmic nature of the intervention based on the 500ms (2 Hz) rate that contributed most to the improvements. This is in line with the expectations of Cummins (2010), who speculated that playground chants were of equal importance to stimulating the processing of phonological skills.

It casts some doubts over previous intervention studies that have made no effort to differentiate between rhythmic qualities found in music and those found in speech, especially when they are highlighted as rhythmic chants. A rhythmic musical intervention is most likely to be more effective than an intervention that uses naturally spoken speech, but not necessarily one that uses rhythmically

spoken speech. The difficulty of comparing like with like is highlighted if one only uses a music based intervention to track improvements in phonological awareness. It is difficult to assess causality.

Bolduc (2009) compared the effect of two music programs on kindergarten children. One music program employed musical activities to increase interest in reading and writing in preschoolers with special needs, whereas the other music program was primarily designed to enhance musical abilities. The music program that focused on enhancing reading and writing was more efficient in enhancing phonological awareness than the other music program. Because there was not a control group without music training, it remains unclear whether both programs significantly enhanced the phonological awareness of the children. Additionally, it is not clear whether the advancement in phonological awareness was due to the music program. I do however agree with one of their conclusions that shows that an enhancement of recreational activities such as involvement in musical games are extremely significant during the pre-school age and involvement in these activities can help pupils to discover, explore and acquire knowledge through spontaneous activities.

In a quasi-experiment, Gromko (2005) investigated the effect of music training on phonological awareness (phoneme segmentation fluency in particular). Children in the treatment kindergarten received music training for 4 months. Children in the control kindergarten received no treatment. Gromko (2005) revealed significantly greater gains in phoneme segmentation fluency in the treatment kindergarten children than in the control kindergarten children. However, because of the pseudo-random assignment of the pre-schoolers to the treatment and the control group, it is not possible to interpret the results unequivocally. Children in the treatment group may have systematically differed from children in the control group with respect to confounding variables. Indeed, Gromko (2005) reported differences in socioeconomic status between the groups. Moreover, the control group did not receive an alternative training. Therefore, the significant gain in the treatment group may simply represent an effect of extra attention (Hawthorne effect).

These issues need to be addressed and in the 2011 a research study (Dege, 2011) reported the results from a research project on the effect of a music program on phonological awareness in pre-schoolers.

This study has a very similar methodology to the one used in this PhD (see Chapter 2) and the findings are comparable.

They, however, compared a music programme and a phonological skills project with a control group who received additional sports tuition. Both groups outperformed the control, but as in this study no difference was found between them. They interpreted the increase of phonological skill level in both groups as evidence of a shared sound category learning mechanism for language and music at preschool age as presented in the “shared sound category learning mechanism hypothesis” proposed by Patel (2008).

Previous research (Zentner, Eerola, 2011) found that infants engaged significantly more in rhythmic movement to music and other rhythmically regular sounds than to either Adult or Infant Directed speech and suggested that the degree of rhythmic coordination with music is positively related to displays of positive affect, eg the infant smiled more when listening to music. The findings are suggestive of a predisposition for rhythmic movement in response to music and other metrically regular sounds. Indeed the infants, aged between 5 and 24 months moved equally well to music as to a more simple acoustic stimuli – an isochronous drum beat. They suggest that if there is a predisposition to move rhythmically and be able to entrain to music perhaps this ability might have another function. According to Patel (2008) one possibility is that the involved brain mechanism has a target of natural selection for music; another is that it evolved for some other function that just happens to be relevant for music processing. It seems possible that many human activities can become more efficient if they are taught rhythmically and even parrots are stimulated to dance in time to music with lyrics (Patel 2009). He speculated that ‘Snowball’ the dancing parrot showed that:-

“entrainment or sustained movement to a musical beat relies on the brain circuitry for complex vocal learning, which requires a tight link between auditory and motor circuits in the brain”. pg 827.

Taub (2007) found evidence that golf swings were improved after a training programme in synchronised metronome tapping at an IOI of 500ms. Just listening to music, both with and without lyrics seems to improve the performance of highly trained athletes.

The correlations from this study align with results from both the pilot study and from previous research into rhythmic accuracy in both drumming and singing. The correlations found in this study are therefore representative of the general population of four to five year-old children. Similarities in findings among the current study, the pilot study, and previous research, suggest that generalization of results to the general population is likely. In addition to generalizability of findings, the correlations support proceeding with further experimental research with children in a classroom situation to examine relationships between rhythmic entrainment and phonological awareness not just using music, but using many other methods of teaching that are dependent on rhythmic stability and complex listening skills, such as dance or perhaps rhythmic gymnastics.

10.7 Research Question 7

- Can we gain a greater understanding of the skills required to process phonological information, and become more able to decode the language in readiness for reading through an increased understanding of the relationship between the rhythmic properties of speech and music?

The answer to this final research question is more ambiguous.

Within this research with 5 year-old children I did find some significant relationships between entrainment and the BAS⁴³ word reading test, but the relationships were not strong. They were however in line with the results shown in the Anvari et al. study (2002) where they found that although the perception of rhythm was significantly associated with phonological awareness, it was not significantly related to single word reading with children of this age.

⁴³ The British Ability Scales Word Reading Test (Elliott, Murray and Pearson, 1977). The BAS is an untimed measure of children's word reading accuracy normed on a UK population, and presents single words graded in difficulty for reading aloud.

The results from this study showed age related differences because the results varied between the studies. In Study 2, where the children had only been engaged in learning letter sounds for less than one school term I found only two significant correlations with the Singing in Time Task at the rates of 400ms and 666ms. In Study1 the children were tested a year after they had been tested in their music, cognitive and P.A ability. These children were now engaged in a full reading curriculum, and I found that their word reading scores correlated with their previous drumming tests at two pulse rates. There were relationships between the drumming to the metronome at 666ms, and a very near significant correlation with Drumming to Music at 400ms ($p = 0.051$). This would suggest as we had previously thought that the entrainment to Drumming might be a more significant measure, rather than Singing in Time, for future success in reading.

11 Conclusions – Future Research

Although there is a long tradition of research that exists on synchronization with simple metronomes (e.g., Dunlap 1910; Fraisse et al. 1958; Woodrow 1932, Parncut, 1994), there is relatively little work on beat perception in sequences where there is rhythmic complexity and slight variations in rhythm. Even stimuli, such as that which I composed for this research, are far more complex than the sounds of a simple metronome. This research shows that when testing the accuracy of young children's responses to isochronous pulse rates they will respond with equal or greater accuracy when they tap to music, especially if it is within their own Western Music culture (Drake & Ben Heni, 2003). It is quite possible that they would respond equally well to 'real time' music, in other words to music that is not computer generated, but is played by 'live' musicians. The children in the Drake trials heard a recording of a piece of music played by an orchestra where isochrony is perceived rather than is actually the case. I would suggest that the success of the children listening to this piece was because the music is very rhythmical, and that rhythmicity is caused by the constant metrical accents not only from the drum but also from the orchestration that mirrors the accents within the music. Of course another aspect of listening to such a piece of music is it is considerably more exciting for the young children which means attention to the piece is greater, and of course it is predictable because of its strong metrical structure.

In the dynamic attending theory of Jones (Jones and Boltz 1989) it was suggested that there are more than one internal 'attentional' rhythm that can become entrained to temporal regularities in the environment or a piece of music. This idea has been implemented with computational models that employ oscillators to model internal rhythms (Large and Jones 1999; Large and Palmer 2002; McAuley 1995). A single oscillator excited by a simple isochronous sequence produces output with a certain degree of variability. A metrical sequence, however, excites several oscillators with periods which are multiples of the basic beat period. Due to the coupling, these different oscillators are drawn into a stable relationship with each other. The models predict improved synchronization to a beat when listening to metrical events such as musical

sequences that are not completely isochronous.

In 'real' music the beat can often be quite variable as the musicians seek to emphasise a phrase. This is termed 'rubato or robbed time' in music. The musician deliberately slows down or speeds up and then returns to the beat at a later time. You can hear this in almost any singing performance. Surprisingly expressive timing variation seems to reduce synchronization accuracy but seems to aid the recovery of metrical structure. Large and Palmer (2002) arrived at similar conclusions on the basis of computational modeling. Snyder and Krumhansl (2001) examined the accuracy of tapping with the beat of piano ragtime pieces as a function of the presence/absence of pitch variation and of the left-hand part. Whereas pitch had little effect, elimination of the left-hand part (which regularly marked the beat) made synchronization more variable.

In recent work on beat perception Patel (2005 - 2011) has used only 'real' music to track the participants ability to synchronise with a beat. The variety of stimuli he uses comes from many types of music:- classical, jazz, rock and 'pop'. The speeds are quite variable but still fall comfortably within the 1000ms to 400ms range. He uses waltzes (triple time) as well as the more usual duple time found in marches or rock music. Significantly they are all recordings of live performances (Some of the rock music will be studio engineered).

The music composed for this study was all generated at a computer, and any variation in synchronisation in initial playing of the parts was brought into perfect synchronization by the software (Sibelius).

Future research should see whether 'live' recordings of music elicit the same results as those found in this study. My instinct is that they would, or might even be improved as they are more 'naturalistic' and contain small fluctuations in pulse and metre. Drake, Penel, and Bigand (2000) asked listeners to tap the pulse of musical excerpts in varied Western tonal styles, each presented mechanically synthesized, mechanically accented, or expressively performed by a concert pianist. Their results confirmed that musicians and non-musicians were readily able to coordinate with temporally fluctuating musical performances. Entrainment with 'expressive' versions occurred at slower frequencies, within a narrower range of synchronization levels. Repp (2002c) showed that synchronization with expressively timed music was better than

synchronization with a sequence of identical tones that mimicked the expressive timing pattern.

The implications for the early years classroom of these findings in the drumming entrainment tasks is quite significant. The response levels of the children to music, be it computer generated or possibly to recorded live music, is equal if not greater than if they respond to a simple metronome task. The more culturally appropriate stimuli generally elicits the greatest response from the children. The question that perhaps arises is whether in an intervention that compared rhythmic speech to 'real' music rather than computer generated music would still have the greater impact on a child's phonological skills.

REFERENCES

- Anderson, S., Himonides, E., Wise, K., Welch, G., Stewart, E. (2012). Is there potential for learning in amusia? A study of the effect of singing intervention in congenital amusia. *Ann. N.Y. Acad. Sci.* 1252 345–353.
- Anthony, J.L., Lonigan, C.J., Burgess, S.R., Driscoll Bacon, K., Phillips, B.M., & Cantor, B.G. (2002). Structure of preschool phonological sensitivity: Overlapping sensitivity to rhyme, words, syllables, and phonemes. *Journal of Experimental Child Psychology*, 82, 65–92.
- Anthony, J. L., Lonigan, C. J., Driscoll, K., Phillips, B. M., & Burgess, S. R. (2003). Phonological sensitivity: A quasi-parallel progression of word structure units and cognitive operations. *Reading Research Quarterly* 38, 470–487.
- Anthony, J. L., & Lonigan, C. J. (2004). The nature of phonological awareness: Converging evidence from four studies of preschool and early grade school children. *Journal of Educational Psychology*, 96, 43–55.
- Anthony, J. L., & Francis, D. J. (2005). Development of phonological awareness. *Current Directions in Psychological Science*, 14(5), 255-259.
- Anvari, S. H., Trainor L.J. Woodside, J. & Levy, B.A. (2002). Relations among musical skills, phonological processing, and early reading ability in pre-school children. *Experimental Child Psychology*, 83, 111-130.
- Arvaniti A. (2009). Rhythm, timing and the timing of rhythm. *Phonetica*, 66: 46-63.
- Aschersleben, G. (2002). Temporal control of movements in sensorimotor synchronization. *Brain and Cognition*, 48:66–79.
- Bacon, C.J., Myers, T.R. and Karageorghis, C.I., (2012) Effect of music-movement synchrony on exercise oxygen consumption, *The Journal of Sports Medicine and Physical Fitness* 52 (4) : 359- 365
- Bamberger, J. (1980). Cognitive structuring in the apprehension and description of simple rhythms. *Archives de Psychologie*, 48, 171-199.
- Bamberger, J. (1999) *Developing Musical Intuitions*. Oxford: OUP.
- Baruch, C., & Drake, C. (1997). Tempo discrimination in infants. *Infant Behavior and Development*, 20(4), 573-577.

- Baron J. Strawson, C. (1977). Mechanisms for pronouncing printed words: Use and acquisition. *Journal of Experimental Psychology: Human Perception and Performance*, Vol 2(3) 386-393.
- Benward, B. (1985). Music in theory and practice. Dubuque, Iowa: Wm. C. Brown Publishers.
- Bergeson, T.R. & Trehub. S.E. (2006). Infants perception of rhythmic patterns. *Music Perception*, 23, 345-360.
- Bertrand, D. (1999). *Groupement rythmique et representation mentale de melodies chez l'enfant* (Unpublished doctoral dissertation). Liège University, Belgium.
- Besson, M. & Schön, D. (2001). Comparison between Language and Music. In R.J. Zatorre and I. Peretz (Eds.), *The Biological Foundations of Music*, Annals of the New York Academy of Sciences, 930, 232-258. New York.
- Besson, M., & Schön, D. (2003). Comparison between language and music. In I. Peretz, & R. Zatorre (Eds.), *The cognitive neuroscience of music* (269-293). New York: Oxford University Press.
- Bhide, A. Power, A. Goswami, U. (2012) A Rhythmic Musical Intervention for Poor Readers: A Comparison of Efficacy with a Letter-Based Intervention. Unpublished masters Study. CNE Cambridge
- Bigand E, Tillmann B, Poulin B, D'Adamo D, Madurell F.(2001).The effect of Harmonic context on phoneme monitoring in vocal music. *Cognition* 81(1), B11–B20.
- Blachman, B.A., Ball, E.W., Black, R.S., & Tangel, D.M. (1994). Kindergarten teachers develop phoneme awareness in low-income, inner-city classrooms. *Reading and Writing: An Interdisciplinary Journal*, 6, 1-18.
- Blachman, B.A., Tangel, D.M., Ball, E.W., Black, R., & McGraw, C.K. (1999). Developing phonological awareness and word recognition skills: A two-year intervention with low-income, inner city children. *Reading and Writing: An Interdisciplinary Journal*, 11(3), 239-273.
- Bishop, D.T., Karageorghis, C.I. and Loizou, G. (2007) A grounded theory of young tennis players' use of music to manipulate emotional state. *Journal of Sport and Exercise Psychology* 29, 584-607.
- Bispham, J. (2006). Rhythm in Music: What is it? Who has it? and Why? *Music Perception* 24(2), 125–134.
- Blacking, J. (1973) *How Musical is Man?* University of Washington.

- Bobin-Bègue, A. & Provasi, J. (2005). Tempo Discrimination in 3- and 4-year-old children: performances and threshold. *Current Psychology Letters*, 16, (2).
- Boets, B., Wouters, J., van Wieringen, A., & Ghesquière, P. (2007). Auditory processing, speech perception and phonological ability in pre-school children at high-risk for dyslexia: A longitudinal study of the auditory temporal processing theory. *Neuropsychologia*, 45(8), 1608-1620.
- Bolduc, J. (2009) Effects of a music programme on kindergartners' phonological awareness skills. *International Journal of Music Education* 27. 37-47.
- Bowey, J. A., & Francis, J. (1991). Phonological analysis as a function of age and exposure to reading instruction. *Applied Psycholinguistics*, 12, 91-121.
- Bradley, L.L. & Bryant, P.E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature*, 310, 419-261.
- Bradley, L.L. & Bryant, P. E. (1985). *Children's Reading Problems*; Oxford: Blackwell.
- Bradley, L., and Bryant, P. 1991. Phonological Skills before and after learning to read. In S. Brady and D. Shankweiler (eds.) *Phonological Processes in Literacy: A tribute to Isabelle Y. Liberman*. Hillsdale, NJ: Erlbaum Associates.
- Bridger, W.H. (1961)"Sensory Habituation and Discrimination in the Human Neonate." *American Journal of Psychiatry*, 117, 991-996.
- Brooks, G (2003) Sound sense: the phonics element of the National Literacy Strategy. A report to the Department for Education and Skills.
- Brown, S. (2001). "The musilanguage' model of music evolution" In Wallin, N. L Merker, B, Brown,S (Eds.). *The Origins of Music*. Cambridge: MIT Press, 271-300.
- Bryant, P.E., Bradley, L., Maclean, M., & Crossland, J. (1989). Nursery rhymes, phonological skills and reading. *Journal of Child Language*, 16(2), 407- 428.
- Bryant, P.E., MacLean, M. Bradley, L.L., & Crossland, J. (1990). Rhyme and alliteration, phoneme detection and learning to read. *Developmental Psychology*, 26, 429-438.
- Bus, A.G. & Ijzendoorn, M.H. (1999). Phonological awareness and early reading: A meta analysis of experimental training studies. *Journal of Educational Psychology*, 91, 403-414.

- Byrne, B., & Fielding-Barnsley, R. (1991). Evaluation of a program to teach phonemic awareness to young children. *Journal of Educational Psychology*, 83, 451-455.
- Caclin A, McAdams S, Smith B, Winsberg S (2005) Acoustic correlates of timbre space dimensions: a confirmatory study using synthetic tones. *Journal of Acoustical Society of America* 118:471–482.
- Calfee, R. C., Chapman, R. S., & Venezky, R. L. (1972). How a child needs to think to learn to read. In L.W. Gregg (Ed.), *Cognition in learning and memory*, 139- 182. New York: Wiley.
- Campbell, P. S. (1991). Rhythmic movement and public school music education: conservative and progressive views of the formative years. *Journal of Research in Music Education* 39, 12–22.
- Carroll, J. M., & Snowling, M. J. (2001). The effects of global similarity between stimuli on children's judgment of rime and alliteration. *Applied Psycholinguistics*, 22, 327–342.
- Chandrasekaran, B., Hornickel, J., Skoe, E., Nicol, T., and Kraus, N. (2009). Context-dependent encoding in the human auditory brainstem relates to hearing speech in noise: implications for developmental dyslexia. *Neuron* 64, 311–319.
- Chang, H. W., & Trehub, S. E. (1977b). Infants' perception of temporal grouping in Auditory patterns. *Child Development*, 48, 1666-1670.
- Chen, J.L., Penhune, V.B., & R.J. Zatorre. (2008). Listening to musical rhythms recruits motor regions of the brain. *Cerebral Cortex*, 18:2844-2854.
- Chukovsky, K. (1968). *From Two to Five* (Translation of the 1959ed.) Berkeley: University of California Press.
- Clarke, E. F. (1987). Categorical rhythm perception: An ecological perspective. In A. Gabrielsson (Ed.), *Action and Perception in Rhythm and Music*, 19-34. Stockholm: Royal Swedish Academy of Music.
- Clark, J., Yallop, C. Fletcher, J (2007). *Introduction to Phonetics and Phonology* (3rd edition ed.). Oxford: Blackwell.
- Clayton, M (2012). What is Entrainment? Definition and applications in musical research. *Empirical Musicology Review* 7, (1-2) 49-56.

- Corriveau, K., Pasquini, E. & Goswami, U. (2007). Basic auditory processing skills, and specific language impairment: a new look at an old hypothesis. *Journal of speech, language and hearing research* 50, 647-666.
- Corriveau, K.H. & Goswami, U. (2009) Rhythmic motor entrainment in children with speech and language impairments: Tapping to the beat. *Cortex*, 45, 119-130.
- Cross, I. (1999). Is music the most important thing we ever did ? *Music, development and evolution*. In Music, mind and science. Suk Won Yi, Ed. Seoul: Seoul National University Press. 10-39.
- Cross, I. (2003). Music and biocultural evolution. *In The Cultural Study of Music: A Critical Introduction* (eds. Martin Clayton, Trevor Herbert, Richard Middleton), Routledge. 19-30.
- Cross, I. (2007). Music and cognitive evolution. In R. I. M. Dunbar & L. Barrett (Eds.), *Oxford handbook of evolutionary psychology*. 649–667. Oxford, England: Oxford University Press.
- Cross, I. (2009). Listening as covert performance. *Journal of the Royal Musical Association*, 134 (1), 67-77.
- Crowder, R.G, Serafine, M. L, Repp, B.H. (1990).Physical interaction and association By contiguity in memory for the words and melodies of songs. *Memory & Cognition* 18(5), 469–476.
- Cummins, F. & Port, R. (1998). Rhythmic constraints on stress timing in English. *Journal of Phonetics*, 26, 145-171.
- Cummins, F. (2010). *Looking for rhythm in speech*. Paper presented at the BPS Language and Music Seminar, Cambridge, 6 – 8 December 2010.
- Cutler, A.(1994). Segmentation problems, rhythmic solutions. *Lingua* 92, 81–104.
- Cutler, A. (1996). Prosody and the word boundary problem. In J. L. Morgan & K. Demuth (Eds.), *Signal to syntax* 87–99. Mahwah, NJ: Erlbaum.
- Cutler, A. (2005). Lexical Stress. In D.B. Pisoni & R.E. Remez (Eds.), *The Handbook of Speech Perception*, pp. 264-289. Oxford: Blackwell
- Dalla Bella S., Peretz I. (2003) Congenital amusia interferes with the ability to synchronize with music. *Annals of the New York Academy of Sciences* , 999: 166–9.e
- Dalla Bella, S., J-F. Giguère & I. Peretz (2007). Singing proficiency in the general population. *Journal of the Acoustical Society of America* , 121, 1182-1189.

- Dalla Bella, S., & Berkowska, M. (2009). Singing proficiency in the majority: Normality and "phenotypes" of poor singing. *Annals of the New York Academy of Sciences*, 1169, 99-107.
- Darwin, C. (1871). *The Descent of Man, and Selection in Relationship to Sex*. (1st ed.), London: John Murray.
- Davies, J.B. (1978). *The psychology of music*. Stanford, CA: Stanford University Press.
- David, D., WadeWoolley, L., Kirby, J. R., & Smithrim, K. (2007). Rhythm and reading development in school-age children: a longitudinal study. *Journal of Research in Reading*, 30(2), 169-183.
- Davidson L (1985) Tonal structures of children's early songs. *Music Perception* 2(3) 361- 373.
- Davidson, L., & Colley, B. (1987). Children's rhythmic development from age 5 to 7: Performance, notation, and reading of rhythmic patterns. In J.C. Peery, I.W.Peery, & T.W.Draper (Eds.), *Music and child development*, 107-136. New York: Springer-Verlag.
- Davidson, L., & Scripp, L. (1988). *Young children's musical representations: Windows on music cognition*. In J.A. Sloboda (Ed.), *Generative processes in music*. 195-230. Oxford: Clarendon Press.
- Davidson, L. (1994) Songsinging by young and old: *A developmental approach to music*. In Aiello R & Sloboda J.A .Eds (1994) *Musical Perceptions*. Oxford: OUP.
- De Bruyn, L. Leman, M. Moelants, D (2009) Does social interaction activate music listeners? *Computer Music Modeling and Retrieval*. (5493), 93-106.
- De Cara, B. & Goswami, U. (2002). Phonological neighbourhood density, effects in a rhyme awareness task in five year old children *Journal of child language* 30, 695 – 710.
- Degé, F., Schwarzer, G. (2011). The Effect of a Music Program on Phonological Awareness in Preschoolers. *Frontiers in Psychology*, 2(124) 1-7.
- Delogu, F., Lampis, G., and Olivetti Belardinelli, M. (2006). Music to language transfer effect: may melodic ability improve learning of tonal languages by native nontonal speakers? *Cognitive Processing* 7, 203-207.

- Delogu, F., Lampis, G., and Olivetti Belardinelli, M. (2010). From melody to lexical tone: musical ability enhances specific aspects of foreign language perception. *European Journal of Cognitive Psychology* 22, 46-61.
- Demany, L., McKenzie, B., & Vurpillot, E. (1977). Rhythm perception in early infancy. *Nature*, 266 (5604), 718–719.
- Dodd, B. & Gillon, G.T. (2001). Exploring the Relationship Between Phonological Awareness, Speech Impairment, and Literacy. *International Journal of Speech-Language Pathology*, 3 (2) , 139-147.
- Dockrell, J. E. & Lindsay, G. (2000). ‘Meeting the needs of children with specific speech and language difficulties’. *European Journal of Special Needs Education*, 15 (1), 24-41
- Dowling, W.J 1988) Tonal structure and children’s early learning of music. In J Sloboda (Ed) *Generative processes in music*, 33-57 Oxford. OUP.
- Dowling, W.J. (1994). Melodic contour in hearing and remembering melodies. In Aiello R & Sloboda J.A (Eds.), *Musical Perceptions*; Oxford: OUP.
- Dowker,A. (1989). Rhyme and alliteration in poems elicited from young children, *Journal of Child Language* 16, 181-202.
- Drake, C. & Gerard, C. (1989). A psychological pulse train: How young children use this cognitive framework to structure simple rhythms. *Psychological Research*, 51, 16-22.
- Drake, C., & Botte, M.C. (1993). Tempo sensitivity in auditory sequences: Evidence for a multiple-look model. *Perception & Psycho- physics*, 54, 277-286.
- Drake, C. (1993a). Influence of age and experience on timing and intensity variations in the reproduction of short musical rhythms. *Psychologica Belgica*, (33) 217-228.
- Drake, C. (1993b). Reproduction of musical rhythms by children, adult musicians, and adult non-musicians. *Perception and psychology*, 53, 25-33.
- Drake, C. (1998). Psychological processes involved in the temporal organization of complex auditory sequences: universal and acquired processes. *Music Perception*, 16 (1), 11-26.
- Drake, C., Jones, M. R., & Baruch, C. (2000). The development of rhythmic attending in auditory sequences: Attunement, reference period, focal attending. *Cognition*, 77, 251-288.

- Drake, C., Penel, A., and Bigand, E. (2000). Why musicians tap slower than nonmusicians. *In Rhythm Perception and Production*, Desain, P. and Windsor, L. (eds), Swets & Zeitlinger, Lisse, 245-248.
- Drake, C. & Ben El Heni, J. (2003). Synchronising with music: Intercultural Differences. *Annals of the New York Academy of Sciences*, 999, 429-437.
- Drake, C., & Bertrand, D. (2003). The quest for universals in temporal processing in music. In I. Peretz & R. Zatorre (Eds.), *The cognitive neuroscience of music* 21-31. New York, NY: Oxford University Press.
- Dunlap K (1910) Reactions to rhythmic stimuli, with attempt to synchronize. *Psychological Review* 17:399–416.
- Echols, C. H. (1996). A role for stress in early speech segmentation. In J. L. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 151-170). Hillsdale, NJ: Erlbaum.
- Ehri, L. C. (1989). The development of spelling knowledge and its role in reading acquisition and reading disability. *Journal of Reading Disabilities*, 22, 356-364.
- ECaR. (2013). Every Child a Reader Annual Report 2011-12 *European Centre for Reading Recovery*, Institute of Education, University of London
- Eimas, P.D. (1985) -The perception of speech in early infancy. *Scientific American*, faculty.washington.edu.
- Elliott, C., Smith, P. and McCulloch, K. (1996). The British Ability Scales-II. London: NFER Nelson.
- Ellis, R. J., & Jones, M. R. (2009). The role of accent salience and joint accent structure in meter perception. *Journal of Experimental Psychology: Human Perception and Performance*, 35(1), 264-280.
- Elmer, S., Meyer, M.; Jäncke, L. (2011) The spatiotemporal characteristics of elementary audiovisual speech and music processing in musically untrained subjects. *International Journal of Psychophysiology*, 1, 59-69.
- Evans, M. A., Shaw, D., & Bell, M. (2000). Home literacy activities and their influence on early literacy skills. *Canadian Journal of Experimental Psychology*, 54, 65–75.
- Evans, J.L, Saffran, J.R, Robe-Torres, K. (2009). Statistical learning in children with specific language impairment. *Journal of Speech, Language and Hearing Research* 52(2):321–335.

- Fant G, and Kruckenberg A. (1996). *On the quantal nature of speech timing*. In Proceedings of the 4th International Conference on Spoken Language Processing, (HT Bunnell and W Idsardi, Eds.), pp. 2036-2039. Wilmington, Delaware, Alfred du Pont Institute.
- Farmer, M.E. & Klein, R.M. (1995). The evidence for a temporal processing deficit linked to dyslexia: A review, *Psychonomic Bulletin and Review* 2: 460–493.
- Fernald, A. (1985). Four month-old infants prefer to listen to motherese. *Infant Behavior and Development*, 8, 181~195.
- Fernald, A. & Kuhl, P. (1987). Acoustic determinants of infant preference for motherese speech. *Infant Behavior and Development*, 10, 279-293.
- Fernald, A. (1989). Intonation and Communicative Intent in Mothers' Speech to Infants: Is the melody the message? *Child Development*, 60, 1497-1510.
- Fisher, N. I. (1993). Statistical analysis of circular data. Cambridge, UK: Cambridge University Press.
- Forgeard, M., Schlaug, G., Norton, A., Rosam, C., Lyengar, U., & Winner, E. (2008). The relation between music and phonological processing in normal-reading children and children with dyslexia. *Music Perception*, 25(4), 383-390.
- Pfordresher, P.Q. & S. Brown (2007). Poor-Pitch in the absence of “Tone Deafness”. *Music Perception*, 25, 95-115.
- Fox, B., Routh, D.K. (1975). Analyzing spoken language into words, syllables, and phonemes: A developmental study. *Journal of Psycholinguistic Research*, 4, 331-342.
- Fox, D. B. (2000). Music and the baby's brain: Early experiences. *Music Educators Journal*, 87(2), 23–27.
- Foundation Stage Profile (2003). Department for Education and Skills. Crown Copyright.
- François, C. Chobert, J. Besson, Schön, D. (2012), Music Training for the Development of Speech Segmentation, *Cerebral Cortex* 10. 2 – 6.
- Fraisse, P. Orlon, G. Paillard, J. (1958) Sur les repères sensoriels qui permettent de contrôler les mouvements d'accompagnement de stimuli périodiques. [On the sensory reference points that make possible the control of movements accompanying periodic stimuli.] *L'Année Psychologique* 58:322–338.

- Frederickson, N., Frith, U., & Reason, R. (1997). *Phonological Assessment Battery*. Windsor: NFER-Nelson.
- Friberg, A., & Sundberg, J. (1995). Time discrimination in a monotonic, isochronous sequence. *Journal of the Acoustical Society of America*, 98, 2524-2531.
- Frostik, R., Bance, L., Lamont, A., Jones, R., Davies, L., & Phillips, A. (n.d.). BBC parent's music room: Child Development Chart. Retrieved from http://www.bbc.co.uk/music/parents/yourchild/childdev_chart.shtml.
- Gardner, H. (1973) *The Arts and Human Development* (New York, Wiley). Gardner, H. (1993) *The Unschooled Mind* (First published 1991) (London, Fontana).
- Gembris, H. (2006). The development of musical abilities. In R. Colwell (Ed.), *MENC handbook of musical cognition and development*. 124–164). New York, NY: Oxford University Press.
- Ghitza, O. & Greenberg, S. (2009). "On the possible role of brain rhythms in speech perception: Intelligibility of time compressed speech with periodic and aperiodic insertions of silence." *Phonetica* 66:113-126.
- Gingold, H., & Abravanel, E. (1987). Music as a mnemonic: the effects of good and bad music setting on verbatim recall of short passages by young children. *Psychomusicology*, 7(1), 25-39.
- Gipstein, M., Brady, S.A., Fowler, A. (2000). Questioning the Role of Syllables and Rimes in Early Phonological Awareness in Baden, N.A. (ed) *Predictions and Prevention of Reading Failure*, 177-216. Baltimore, Maryland, York Press, Inc.
- Goldstein, D. M. (1976). Cognitive-linguistic functioning and learning to read in pre-schoolers. *Journal of Experimental Psychology*, 68, 680-688.
- Gooding, L., Standley, J.M. (2011). Musical Development and Learning Characteristics of Students. A Compilation of Key Points From the Research Literature Organized by Age, *Applications of Research in Music education Online Sage Journals*.
- Gordon, R. L., Schön, D., Magne, C., Astésano, C., & Besson, M. (2010). Words and melody are intertwined in perception of sung words: EEG and behavioral evidence. *PLoS ONE*, 5(3), -9889
- Gordon, R.L. Magne, C.L. Large, E. (2011). EEG Correlates of Song Prosody: A New Look at the Relationship between Linguistic and Musical Rhythm. *Frontiers in psychology*, 2, 352.

- Goswami, U. (1993), Phonological Skills and Learning to Read. *Annals of the New York Academy of Sciences*, 682: 296–311.
- Goswami, U. (2001). Early phonological development and the acquisition of literacy. In S. B. Neuman & D. K. Dickinson (Eds.), *Handbook of early literacy research* (111-125). New York, NY: Guilford Press.
- Goswami, U. (2005 Dec). Synthetic Phonics and Learning to Read: A Cross-language Perspective. *Educational Psychology in Practice*, 21 (4).
- Goswami, U. (2011) “A temporal sampling framework for developmental dyslexia.” *Trends Cognitive Science* 15(1), 3-10. 548–567.
- Goswami, U. (2012). Language, Music and Children’s Brains: A Rhythmic Timing Perspective on Language and Music as Cognitive Systems. *Commentary for Peretz paper Music, Language & Modularity in Action. Action in Language and Music as Cognitive Systems*, (Eds) Patrick Rebuschat, Martin Rohmeier, John A. Hawkins, and Ian Cross. OUP
- Goswami, U. & Bryant, P (1990). *Phonological Skills And Learning To Read*. London: Psychology Press.
- Goswami, U., Ziegler, J. C. Dalton, L. & Schneider, W. (2001). Pseudo-homophone effects and phonological recoding procedures in reading development in English and German. *Journal of Memory & Language*, 45(4), 648–664. et al. (Eds.) *Language and Music as Cognitive Systems*.
- Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2003). Nonword reading across orthographies: How flexible is the choice of reading units? *Applied Psycholinguistics*, 24, 235–247.
- Goswami, U., Thomson, J. Richardson, U. Stainthorp, R. Hughes, D. Rosen, S. et al. (2002) Amplitude envelope onsets and developmental dyslexia: A new hypothesis. *Proceedings of the National Academy of Sciences of the United States of America*, 99(16): 10911-10916.
- Goswami, U., Gerson, D., & Astruc, L. (2010). Amplitude envelope perception, phonology and prosodic sensitivity in children with developmental dyslexia. *Reading & Writing*. 23(8), 995-1019.
- Goswami U., Fosker T, Huss M, Mead N, and Szucs D. (2010). Rise time and formant transition duration in the discrimination of speech sounds: The Ba-Wa distinction in developmental dyslexia. *Developmental Science*, published online.

- Goswami U., Huss, M. Fosker, T. Mead, N. Verney, J.P. (2012). Perception of patterns of musical beat distribution in phonological developmental dyslexia: Significant correlations with word reading comprehension. *Cortex* 830.(accepted manuscript May 2012)
- Gottfried, T. L., Staby, A. M., and Ziemer, C. J. (2004). Musical experience and mandarin tone discrimination and imitation. *Journal of Acoustical Society of America* 115, 2545.
- Grahn, J.A., Brett, M. (2007). Rhythm and Beat Perception in Motor Areas of the Brain *Journal of Cognitive Neuroscience* 19(5), 893–906
- Greenberg, Y., Tsuzaki, M., Kato, K., and Sagisaka, Y. (2006) “A trial of communicative prosody generation based on control characteristic of one word utterance observed in real conversational speech”, *Proc. Speech Prosody* 37-40.
- Gromko, J.E. (2009). Effects of temporal sequencing and auditory discrimination on children’s memory patterns for tones, numbers and nonsense words *Journal of Research in Music Education*. 57 (2), 140-151.
- Habsen, D., Bernstorf, E., & Stuber, G. (2004). *The music and literacy connection*. MENC: The National Association for Music Education.
- Hallam S, (1998) *Instrumental Teaching*, Oxford, Heinemann Educational Hallam, S. (2006). *Music Psychology in Education*, London: Institute of Education, University of London.
- Hallam, S. (2010) 'The power of music: its impact of the intellectual, personal and social development of children and young people', *International Journal of Music Education* 38(3), 269-289.
- Halle, J., & Lerdahl, F. (1993). A generative textsetting model. *Current Musicology*, 55(3-23).
- Hämäläinen, J., Leppänen, P.H.T., Torppa, M., Müller, K. and Lyytinen, H. (2005). Detection of sound rise time by adults with dyslexia. *Brain and Language*, 94: 32-42.
- Hannon, E. E., Snyder, J. S., Eerola, T., & Krumhansl, C. L. (2004). The role of melodic and temporal cues in perceiving musical meter. *Journal of Experimental Psychology: Human Perception and Performance*, 30, 956-974.

- Hannon, E.E. & Johnson S, P. (2005). Infants use meter to categorise rhythms and melodies: Implications for musical structure learning *Cognitive Psychology*. 50 (4), 354-77.
- Hannon, E. E., Trehub, S. E., & Purves, D. (2005). Tuning in to musical rhythms: Infants learn more readily than adults. *Proceedings of the National Academy of Sciences of the United States of America*, 102, 12639–12643.
- Hannon, E.E., & Schellenberg, E.G. (2008). Speech and music perception: Initial abilities and early development. In Bruhn, Kopiez, Lehmann, & Oerter (Eds.), *Musikpsychologie: Das neue Handbuch*. Reinbek bei Hamburg: Rowolht Verlag. 131-142.
- Hannon EE, Soley G, Ullal S. (2012). Familiarity overrides complexity in rhythm perception: a cross-cultural comparison of American and Turkish listeners. *Journal of Experimental Psychology Human perception and performance*, 20, 0096-1523.
- Hargreaves, D. J. (1986). The developmental psychology of music. Cambridge: Cambridge University Press.
- Hargreaves, D. J., Zimmerman, M.P. (1992). Developmental Theories of Music Learning. In: R. Colwell (Ed.), *Handbook of Research on Music Teaching and Learning*. 377-391. New York: Schirmer.
- Harper, L. J. (2011). Nursery rhyme knowledge and phonological awareness in pre-school children. *The Journal of Language and Literacy Education* [Online], 7(1), 65-78.
- Hecht, S. A., Burgess, S. R., Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2000). Explaining social class differences in growth of reading skills from beginning kindergarten through fourth-grade: The role of phonological awareness, rate of access, and print knowledge. *Reading and Writing: An Interdisciplinary Journal*, 12, 99–127.
- Hickok, G., and Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience* 8, 393-402.
- Hill, P. (1995). School effectiveness and improvement: Present realities and future possibilities. *Dean's Research Seminar Series. Inaugural Professorial Lecture*, 24 May, 1995, Faculty of Education, The University of Melbourne.
- Hodges, D. A. (1996). *Handbook of music psychology*. San Antonio, TX: Institute for Music Research Press.

- Hoequist, C.A. (1983) The perceptual centre and rhythm categories. *Language and Speech*, 26, 367-376.
- Honing, H., Ladinig, O., Winkler, I., & Haden, G. (2009). Is beat induction innate or learned? Probing emergent meter perception in adults and newborns using event-related brain potentials (ERP). *The Neurosciences and Music III, Disorders and Plasticity: Annals of the New York Academy of Sciences*, 1169, 93–96.
- Honing, H. (2011b). The illiterate listener. *On music cognition, musicality, and methodology*. Amsterdam:Amsterdam University Press.
- Honing, H., Ploergerb, A. (2012). Cognition and the Evolution of Music: Pitfalls and Prospects, *Topics in Cognitive Science online*.
- Hooper, S. R., & Umansky, W. (2009). Principles of development. Retrieved from <http://www.education.com/reference/article/principles-development>.
- Hulme, C., Hatcher, P.J et al (2002). Phoneme awareness is a better predictor of Early reading skill than onset/rime awareness *Journal of Experimental Psychology*, 82, 2-28.
- Hulson, E. (1929). Tempo in rhythm for young children. *Childhood Education*, 6 (2) 78-80
- Huron, D. Royal, M. (1996). "What is melodic accent? Converging evidence from musical practice." *Music Perception*, Vol. 13, (4) 489-516.
- Huss, M., Verney, J.P. Fosker, T. Fegan, N. Goswami, U. (2011). Music, rhythm, rise time perception and developmental dyslexia. *Cortex*, 47, (6). 674-689.
- Hyde, K.L., and Peretz, I. (2004) Brains that are out of tune but in time. *Psychological Science*, 15: 356-360.
- Jaques-Dalcroze, E. (1980) *Rhythm, Music & Education*. – London.
- James, D. (2005). Phonological Awareness in Deaf Children Who Use Cochlear Implants. *Journal of Speech, Language, and Hearing Research*, 48, 511-1528.
- Jentschke, S., Koelsch, S. & Freiderici, A.D. (2005). Investigating the relationship of music and language in children: Influences of musical training and language impairment. *Annals of the New York Academy of Sciences*, 1060, 231-242.
- Jentschke, S., Koelsch, S. Sallat, S, Freiderici, A.D. (2008). Children with Specific Language Impairment Also Show Impairment of Music-syntactic Processing *Journal of Cognitive Neuroscience* 20, (11) 1940 -1951

- Johnston, R.S. & Watson, J.E. (2003). Accelerated Reading and Spelling with Synthetic Phonics – a five year follow up. Insight 4. Scottish Executive Education Department. *Journal of Experimental Child Psychology*, 49, 323-340.
- Johnston, R.S. & Watson, J.E. (2004). Accelerating the development of reading, spelling and phonemic awareness skills in initial readers. *Reading and Writing*, 17 (4). 327-357.
- Jones, M.R. & Boltz, M. (1989). Dynamic Attending and responses to time *Psychology Review* 96, 459-451.
- Jones, M. R., & Pfordresher, P. Q. (1997). Tracking melodic events using joint accent structure. *Canadian Journal of Experimental Psychology*, 51, 271–291. *Journal of Experimental Child Psychology* 82, (2002).
- Juel, C. (1988).“Learning to Read and Write: A Longitudinal Study of 54 Children from First Through Fourth Grades.” *Journal of Educational Psychology*, 80 (4) 443-47.
- Jusczyk, P.W., Kemler Nelson, D.G, Hirsh-Pasek, Kennedy, L.J, Woodward, A. & Piwoz. J (1992). Perception of acoustic correlates of major phrasal units by young infants. *Cognitive Psychology*, 24, 252- 293.
- Jusczyk, P.W., A. Cutler, and N. Redanz. (1993). “Preference for the predominant stress patterns of English words”. *Child Development* 64: 675-687.
- Jusczyk, R., & Krumhansl, C. (1993). Pitch and rhythmic patterns affecting infants’ sensitivity to musical phrase structure. *Journal of Experimental Psychology: Human Perception and Performance*, 19 (3), 627–640.
- Jusczyk, P. W., & Luce, P. A. (2002). Speech perception. In H. Pashler & S. Tantis (Eds.), *Steven’s handbook of experimental psychology*: Vol. 1. Sensation and perception (3rd ed) 493–536). New York: Wiley.
- Kaufman, A. S., & Kaufman, N. L. (1990). Kaufman Brief Intelligence Test. Circle Pines, MN: AGS Publishing.
- Register, D. (2001). The effects of an early intervention music curriculum on prereading/ writing. *Journal of Music Therapy*, 38, 239-248.
- Kenney, S. H. (1997). Music in the developmentally appropriate integrated curriculum. In C. H. Hart, D. C. Burts, & R. Charlesworth (Eds.), *Integrated curriculum and developmentally appropriate practice* (103–144). Albany: State University of New York Press.

- Kessen, W., Levine, J., & Wendrich, K.A. (1979). The imitation of pitch in infants. *Infant Behavior and Development*, 2, 93-99.
- Kimball, C. (1996). *Song: a guide to style and literature*. Washington: Pst...Inc
- Kirschner, S., Tomasello, M. (2009) Joint drumming: Social context facilitates synchronization in preschool children. *Journal of Experimental Child Psychology* 102 (2009) 299–314.
- Kodály, Z. (1974) *The Selected Writings of Zoltán Kodály*. Trans. Lily Halápy and Fred Macnicol. London: Boosey & Hawkes .
- Koelsch, S. & Grossman, T. Gunter, T.C. Hahne, A. Schroger, E. Freidericki, A. (2003). Children processing music, *Cognitive Neuroscience*, 15, 683-693.
- Koelsch, S. Fritz, T. Schultz, K. Alsop, D. & Schlaug, G. (2005). Adults and children processing music: an fMRI study. *Neuroimage*, 25, 1068-1076.
- Koelsch S., Fritz, T., Schlaug, G. (2008). Amygdala activity can be modulated by unexpected chord functions during music listening. *NeuroReport* 19 (18). 1815-1819.
- Kotz, S., Schwartze, M. (2010). Cortical speech processing unplugged: a timely subcortico-cortical framework. *Trends in Cognitive Sciences*, 14 (9), 392 – 399.
- Krumhansl, C.L. & Jusczyk, P.W. (1990). Infants' perception of phrase structure in music. *Psychological Science*, 1, 70-73.
- Krumhansl, C. L. (2000). Rhythm and pitch in music cognition. *Psychological Bulletin*, 126(1), 159-179.
- Kujala, T., Myllyviita, K., Tervaniemi, M., Alho, K., Kallio, J., & Naatanen, R. (2000). Basic auditory dysfunction in dyslexia as demonstrated by brain activity measurements. *Psychophysiology*, 37, 262-266.
- Lamb, S. J. & Gregory, A. H. (1993). The relationship between music and reading in beginning readers. *Educational Psychology*, 13, 13-27.
- Lathroum, L.M. (2011) The role of Music Perception in predicting phonological awareness in five-and six-year-old children. University of Miami (open access PhD. Dissertation)
- Large, E. W., Fink, P., and Kelso, J. A. S. (2002). Tracking simple and complex sequences. *Psychological Research*, 66, 3-17.
- Large E, and Jones MR. (1999). The dynamics of attending: how we track time-varying events. *Psychological Review*, 106, 119-159.

- Large E.W; Palmer C. (2002). Perceiving temporal regularity in music. *Cognitive Science* 26:1–37.
- Large, E. W. (2008). Resonating to musical rhythm: Theory and experiment. In Simon Grondin, (Ed.) *The Psychology of Time*. West Yorkshire: Emerald.
- Lee, C. H., and Hung, T. H. (2008). Identification of Mandarin tones by English speaking musicians and non- musicians. *Journal of Acoustical Society of America* 124, 3235-3248.
- Lehiste I. Suprasegmentals. Cambridge, Massachusetts/London, England: The M.I.T. Press, 1970.
- Leong V, Hämäläinen J, Soltesz F, & Goswami U (2011). Rise Time Perception and Detection of Syllable Stress in Adults with Developmental Dyslexia. *Journal of Memory and Language*, 64, 59-73
- Lerdahl, F. & Jackendorff, R. (1983). *A Generative Theory of tonal music*. Cambridge MA: MIT Press.
- Letters and Sounds (2007). Department for Education and Skills (DfES).
- Liberman, I.Y., Shankweiler, D., Fischer, F.W. and Carter, B. (1974). Explicit syllable and phoneme segmentation in young children. *Journal of Experimental Child Psychology*, 18, 201-212.
- Liberman, M. (1975) *The intonational system of English*. PhD thesis, M.I.T., Cambridge, MA. Published by Indiana University Linguistics Club, 1978
- Liberman, M. & Prince, A. (1977) On stress and linguistic rhythm, *Linguistic Inquiry*, 8, 249 —336
- Lidji, P., Jolicoeur, P., Moreau, P., Kolinsky, R., & Peretz, I. (2009). Integrated preattentive processing of vowel and pitch: a mismatch negativity study. *Annals of the New York Academy of Sciences*, 1169, 481-484.
- Lidji, P., Palmer, C, Peretz, I, Morningstar, M. (2011). Listeners feel the beat: Entrainment to English and French speech rhythms, *Psychonomic bulletin & review*, 18:1035–1041.
- Lindsay, G., Desforges, M., Dockrell, J., Law, J., Peacey, N, Beecham, J., (2008), Effective and Efficient Use of Resources in Services for Children and Young People with Speech, *Language and Communication Needs*. RW053 (Nottingham: Department for Children, Schools and Families (DCSF))

- Lindsay, G, Lindsay, G and Strand, S.(2007), Longitudinal patterns of behavior problems in children with specific speech and language difficulties: child and contextual factors. *British Journal of Educational Psychology*, 77, 811–828.
- Locke, A., Ginsburg, J. Peers, L. (2002) Development and disadvantage implications for the early years and beyond. *International Journal of language and communication disorders* 37, 3-15.
- London, J. (2012). Three Things Linguists Need to Know About Rhythm and Time in *Music Empirical Musicology Review* 7, (1-2) 5-11
- Lonigan, C. J. (2004b). Emergent literacy skills and family literacy. In B. Wasik (Ed.), *Handbook on family literacy: Research and services* , 57-82. Hillsdale, NJ: Lawrence Erlbaum.
- Lonigan, C. J., Burgess, S. R., Anthony, J. L., & Barker, T. A. (1998). Development of phonological sensitivity in two- to five-year-old children. *Journal of Educational Psychology*, 90, 294-311.
- Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent variable longitudinal study. *Developmental Psychology*, 36, 596–613.
- Lonigan, C. J. (2003). Development and promotion of emergent literacy skills in pre-school children at risk of reading difficulties. In B. Foorman (Ed.), *Preventing and remediating reading difficulties: Bringing science to scale* (23–50). Timonium, MD: York.
- Lonigan, C. J. (2007a). Development of the components of phonological awareness across the preschool year. Unpublished manuscript.
- Lonigan, C. J. (2007b). Vocabulary development and the development of phonological awareness skills in preschool children. In R. K. Wagner, A. E. Muse, & K. R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension*, 15–31. New York: Guilford.
- Loong, C., and Lineburgh, N. (2000). *Research in early childhood music: 1929-1999*. Kodály Envoy, 26 (4), 24-29, 34.
- Lumsden, D. V., Nicholson, D. Hilsdon, L. Head, N. Verney, J.P. (2007). *SoundsGreat*. Northumberland County Council, Northumberland Care Trust. Morpeth: Northumberland County Council.

- Lundberg I. (1978) Aspects of linguistic awareness related to reading. In the *Child's Conception of Language*, eds, A Sinclair: R.J. Jarvella, and W.J.M. Levelt. Berlin: Springer-Verlag.
- Lundberg, I., Frost, J & Petersen, O.P. (1988). Effects of an extensive programme for stimulating phonological awareness in preschool children. *Reading Research Quarterly* 33, 263-284.
- Lundberg, I. (1991). Phonemic awareness can be developed without reading instruction. In S. A. Brady & D. P. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* (47–53). Hillsdale, NJ: Erlbaum.
- MacDougall H.G., Moore S.T. (2005). Marching to the beat of the same drummer: The spontaneous tempo of human locomotion. *Journal of Applied Physiology*, 99, 1164-1173.
- MacLean, M., Bryant, P.E., & Bradley, L. (1987). Rhymes, nursery rhymes and reading in early childhood. *Merrill-Palmer Quarterly*, 33, 255-281.
- Madison, G. & Merker, B. (2002). On the limits of anisynchrony in pulse attribution. *Psychological Research*, 66, 201-207.
- Magne, C., Schon, D. & Besson, M. (2006) Musician children detect pitch violations in both music and language better than nonmusician children: behavioural and electrophysiological approaches, *Journal of Cognitive Neuroscience*, 18: 199-211
- Magne, C., Astésano, C., Aramaki, M., Ystad, S., Kronland-Martinet, R., and Besson, M. (2007). Influence of syllabic lengthening on semantic processing in spoken french: behavioral and electrophysiological evidence. *Cerebral. Cortex* 17, 2659–2668.
- Majsterek, D. J., Shorr, D. N., & Erion, V. L. (2000). Promoting early literacy through rhyme detection activities during Head Start circle-time. *Child Study Journal*, 30(3), 143–151
- Mardia, K. V., & Jupp, P. E. (2000). Directional statistics. New York: John Wiley.
- Marie C, Magne C, and Besson M. (2011). Musicians and the metric structure of words. *Journal of Cognitive Neuroscience*, 23(2), 294-305.
- Mattys, S.L., White, L., Melhorn, J.F., 2005. Integration of multiple speech segmentation cues: a hierarchical framework. *Journal of Experimental Psychology General*, 134, 477-500.

- McAuley, J. D. (2006). The Time of Our Lives: Life Span Development of Timing and Event Tracking. *Journal of Experimental Psychology*, 135, (3), 348–367.
- McPherson, G. E. (2006). (Ed.) *The child as musician: A handbook of musical development*. New York, NY: Oxford University Press.
- Meyer, L. B. (1973). *Explaining music: Essays and explorations*. Berkley: University of California Press
- Moelants, D. (2002). Preferred tempo reconsidered. In Stevens, C., Burnham, D., McPherson, G., Schubert, E., and Renwick, J., editors, *Proceedings of the 7th International Conference on Music Perception and Cognition*, 580–583. Adelaide: Causal Productions.
- Montague, K. J. (2002). Music and reading: Evidence for shared cognitive processes and implications for theory, diagnosis and treatment of dyslexia. *Unpublished M.A. thesis*, Tufts University.
- Moog, H. (1976). The development of musical experience in children of pre-school age. *Psychology of Music*, 12, 38-45.
- Moorhead, G. E. & Pond, D. (1978) *Music of young children* (Santa Barbara, CA, Pillsbury Foundation for Advancement of Music Education) (reprinted from works published in 1941, 1942, 1944, and 1951).
- Moreno S, Marques C, Santos A, Santos M, Castro, SL and Besson M. (2009). Musical training influences linguistic abilities in 8-year-old children : More evidence for brain plasticity. *Cerebral Cortex*, 19, 712-23.
- Moreno, S., Bialystok, E., Barac, R., Schellenberg, E.G., Cepeda, N.J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological Science*, 22, 1425-1433.
- Moritz, C. E. (2007). Relationships between phonological awareness and musical rhythm subskills in kindergarten children and comparison of subskills in two schools with different amounts of music instruction (Unpublished master's thesis). Tufts University, Somerville, MA.
- Morris, T., & Leavey, G. (2006). Promoting phonological awareness in nursery-aged children through a Sure Start Early Listening programme. *International Journal of Early Years Education*, 14, 155-168.
- Morrongiello, B.A, Roes, C.L. (1990). Children's memory for new songs: Integration or independent storage of words and tunes? *Journal of Experimental Child Psychology*, 50(1), 25-38.

- Morton, J., Marcus, S.M. & Frankish, C. (1976). Perceptual centres (P-centres). *Psychological Review*, 83, 405-408.
- Musacchia, G., Sams, M., Skoe, E., & Kraus, N. (2007). Musicians have enhanced subcortical auditory and audiovisual processing of speech and music. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 15894-15898.
- Muter, V., Hulme, C., & Snowling, M. (1997). *Phonological Abilities Test*. London: Psychological Corporation.
- Muter, V., Hulme, C. & Snowling, M. (1997). *The Phonological Abilities Test*. London: Psychological Corporation.
- Muter, V., Hulme, C., Snowling, M., & Taylor, S. (1998). Segmentation, not rhyming, predicts early progress in learning to read. *Journal of Experimental Child Psychology*, 71, 3–27.
- Miyamoto, K. A. (2007). Musical characteristics of preschool-age students: A review of literature. Update: *Applications of Research in Music Education*, 26(1), 26–40.
- Nicolson, R.I., Fawcett, A.J., & Dean, P. (1995). Time estimation in developmental dyslexia: Evidence of cerebellar involvement. *Proceedings of the Royal Society*, 259, 43-47.
- Neuhaus, C., & Knösche, T. R. (2006). Processing of rhythmic and melodic Gestalts. An ERP study. *Music Perception*, 24, 209-222.
- Olsho, L.W. (1984). Infant frequency discrimination. *Infant behavior and development*, 7, 27-35.
- Overy, K. (2000). Dyslexia, Temporal Processing and Music; The potential of music as an early learning aid for dyslexic children, *Psychology of Music*, vol. 28, no.2, 218-229.
- Overy, K. (2003). Dyslexia and music: From timing deficits to musical intervention. *Annals of the New York Academy of Sciences*, 999, 497–505.
- Overy, K., Nicolson, R.I., Fawcett, A.J., & Clarke, E.F. (2003). Dyslexia and music: measuring musical timing skills. *Dyslexia*, 9, 12-36.
- Pallone, G., Boussard, P., Daudet, L., Guillemain, P., and Kronland- Martinet, R. (1999). “A wavelet based method for audio-video synchronization in broadcasting applications,” in *Proceedings of the Conference on Digital Audio Effects Trondheim*, 59–62.

- Palmer, C., & Kelly, M. (1992). Linguistic Prosody and Musical Meter in Song. *Journal of Memory and Language*, 31(4), 525-542.
- Papousek, H., & Papousek, M. (1982). Integration into the social world: Survey of re- search. In P. Stratton (Ed.), *Psychobiology of the human newborn* . 367– 390. New York: Wiley.
- Papousek, M., Papousek, H. & Symmes, D. (1991). The meanings of melodies in motherese in tone and stress languages. *Infant Behavior and Development*, 14, 415-440.
- Papousek, H. (1996) Musicality in Infancy Research: biological and cultural origins of early musicality. In Deliege and Sloboda (Ed.) *Musical Beginnings*. Oxford: OUP.
- Parncutt, R. (1994). A perceptual model of pulse salience and metrical accent in musical rhythms. *Music Perception*, 11, 409–464.
- Patel, A., & Peretz, I. (1997). Is music autonomous from language? A neuropsychological appraisal. In I. Deliege, and J. Sloboda (Eds.), *Perception and cognition of music*, 191-215. New York: Psychology Press.
- Patel, A.D. (2003). Language, music, syntax and the brain. *Nature Neuroscience* 6(7),674-681.
- Patel, A.D., Iversen, J.R., Chen, Y., & Repp, B.H. (2005). The influence of metricality and modality on synchronization with a beat. *Experimental Brain Research*, 163:226-238.
- Patel, A.D. (2008). *Music, Language and the Brain*. Oxford. OUP.
- Patel, A.D., Iversen, J.R., Bregman, M. R., Schulz, I. (2009) Experimental Evidence for Synchronization to a Musical Beat in a Nonhuman Animal. *Current Biology* 19, 827–830.
- Patel AD (2011) Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology* 2:142.
- Peretz, I., Champod, A.S. & Hyde, K. (2003). Varieties of musical disorders: The Montreal battery of evaluation of Amusia. *Annals of the New York Academy of Sciences*. 999. 58-73. New York.
- Peretz I. & Coltheart. M (2003). Modularity of music processing. *Nature Neuroscience* 6 (7), 688-691.

- Peretz I, Radeau M, Arguin M. (2004). Two-way interactions between music and language: Evidence from priming recognition of tune and lyrics in familiar songs. *Memory & Cognition*, 32(1),142-152.
- Peretz, I., & Zatorre, R.J. (2005). Brain organization for music processing. *Annual Reviews Psychology*, 56, 89-114.
- Pfordresher, P., & Dalla Bella, S. (2011). Delayed auditory feedback and movement. *Journal of Experimental Psychology: Human Perception and Performance*, 7(2), 566-79.
- Perry, C. & Ziegler, J. C. (2000). Linguistic difficulties in childhood constrain adult reading. *Memory & Cognition*, 28, 739-745.
- Phillips, B. M., & Lonigan, C. J. (2005). Social correlates of emergent literacy. In C. Hulme & M. Snowling (Eds.), *The science of reading: A handbook*, 173-187. Malden, MA: Blackwell.
- Phillips, B.M., Clancy-Menchetti, J., Lonigan, C.J. (2008). Successful phonological awareness instruction with preschool children: Lessons from the classroom. *Topics in Early Childhood Special Education*, 28, 3-17.
- Phillips-Silver, J. & Trainor, L.J. (2005). Feeling the beat: movement influences infants' rhythm perception. *Science* , 308 (5727), 1430.
- Phillips-Silver, J. & Trainor, L.J. (2007). Hearing what the body feels: Auditory encoding of rhythmic movement. *Cognition*, 105, 533-546.
- Phillipot, C. (2001) *Issues in Music Teaching*. Routledge
- Piaget, J., (1951) *Play, Dreams and Imitation in Childhood*, London: Routledge.
- Pickering, S. & Gathercole, S. (2001). *Working test battery for children*. London: The Psychological Corporation.
- Pierrehumbert J. (2003). Phonetic diversity, statistical learning and acquisition of phonology. *Language and Speech*, 46: 115-154.
- Pinker, S. (1997) *How the Mind Works*. London. Allen Lane
- Plantinga, J; Trainor,L.J. (2005) "Memory for melody: infants use a relative pitch code," *Cognition* 98, 1-11.
- Port, R. (2003) Meter and speech. *Journal of Phonetics*, 31: 599-611
- Pouthas, V. (1996). 'The development of the perception of time and temporal regulation of action in infants and children', in Deliège, I. and Sloboda, J., (Eds). *Musical Beginnings*, Oxford: Oxford University Press

- Pufpaff, L.A. (2009). A developmental continuum of phonological sensitivity skills. *Psychology in the Schools, Vol. 00(0)* Wiley Periodicals, Inc.
- Purnell-Webb, P., & Speelman, C. P. (2008). Effects of music on memory for text. *Perceptual and Motor Skills, 106*(3), 927-957.
- Radocy, R. E., & Boyle, J. D. (2003). *Psychological foundations of musical behavior* (4th ed.). Springfield, IL: Charles C. Thomas Publisher.
- Rainbow, E. L. (1977). A longitudinal study of the rhythmic ability of preschool children. *Bulletin of the Council for Research in Music Education, 50*, 52–61.
- Rainbow, E.L., & Owen, D. (1979). A progress report on a three year investigation of the rhythmic ability of pre-school aged children. *Council for Research in Music Education Bulletin, 59*, 84-86
- Rainbow, E. (1981). A final report on a three-year investigation of the rhythmic abilities of pre-school aged children. *Council for Research in Music Education Bulletin, 66/67*. 69-73.
- Reifinger, J. L. (2006). Skill development in rhythm perception and performance: A review of literature. Update: *Applications of Research in Music Education, (1)*, 5–27.
- Repp, B.H. (2001). Phase correction, phase resetting, and phase shifts after subliminal timing perturbations in sensorimotor synchronization. *Journal of Experimental Psychology-Human Perception and Performance, 27*(3) 600-621.
- Repp, B. H. (2002c). Phase correction in sensorimotor synchronization: Nonlinearities in voluntary and involuntary responses to perturbations. *Human Movement Science, 21*, 1–37.
- Repp, B. H. (2005). Sensorimotor synchronization: A review of the tapping literature. *Psychonomic Bulletin & Review, 12*, 969–992
- Robertson, C., & Salter, W. (1997). *The phonological awareness test*. East Moline, IL: LinguiSystems, Inc.
- Rose, J. (2006). Independent Review of the teaching of Early Reading. DfES
- Rosner, J. & Simon, D. (1971). Test of Auditory Analysis Skill, TAAS. *Journal of Learning Disabilities, 4*, 40-48.
- Rosner, J. (1979). *Test of Auditory Analysis Skills*. Novato, CA: Academic Therapy Publications.
- Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition, 70*, 27-52.

- Saffran, J. R. (2003). Musical learning and language development: *Annals of the New York Academy of Sciences*, 999, 397-401. New York.
- Scarborough, H.S. (1998). Early identification of children at risk for reading disabilities: Phonological awareness and some other promising predictors. 77-121. In *Specific Reading Disability: A View of the Spectrum*, (B.K. Shapiro. Eds). Timonium, MD: York Press.
- Schellenberg, E.G. & Hallam, S. (2005). Music listening and cognitive abilities in 10 and 11 year olds: The Blur effect. *Annals of the New York Academy of Sciences*, 1060, 202-209.
- Schellenberg, E.G. & Peretz, I. (2008). Music, language and cognition: unresolved issues *Trends in Cognitive Sciences*, 12, (2), 45-46.
- Schlaug G, Marchina S, Norton A. (2008) From singing to speaking: why patients with Broca's aphasia can sing and how that may lead to recovery of expressive language functions. *Music Perception* 25:315-323.
- Schlaug G, Marchina S, Norton A. (2009) Evidence for Plasticity in White-Matter Tracts of Patients with Chronic Broca's Aphasia Undergoing Intense Intonation-based Speech Therapy. *Ann NY Acad Science*. 1169:385-394.
- Schneider, W., Ennemoser, M. Roth, E. & Kuespert, P. (1999). Kindergarten prevention of dyslexia: Does training in phonological awareness work for everybody? *Journal of Learning Disabilities*, 32, 429-436.
- Schön, D., Magne, C., and Besson, M. (2004). The music of speech: music facilitates pitch processing in language. *Psychophysiology* 41, 341-349.
- Schön, D., Boyer, M., Moreno, S., Besson, M., Peretz, I. & Kolinsky, R. (2008). *Songs as an aid for language acquisition. Cognition*, 106, 975-983
- Schön, D., Gordon, R., Campagne, A., Magne, C., Astesano, C., Anton, J. L., et al. (2010). Similar cerebral networks in language, music and song perception. *NeuroImage*, 51(1), 450-461.
- Scott, S. K. (1998). The point of P-centres. *Psychological Research/Psychologische Forschung*, 61(1), 4-11.
- Serafine, M. L., Crowder and Repp, B. (1984). Integration of melody and text in memory for songs. *Cognition*, 16, 285-303.
- Serafine, M. L., Davidson, J. and Crowder, R. G. (1986). On the nature of melody. Text Integration in memory for songs. *Journal of memory and language*, 25, 123-135.

- Serafine M.L, (1988) *Music as Cognition The development of thought in sound*
Columbia University Press :New York
- Shaywitz, B. A., Lyon, G. R., & Shaywitz, S. E. (2006). The role of functional magnetic resonance imaging in understanding reading and dyslexia. *Developmental Neuropsychology*, 30, 613-632.
- Sloboda, J.A. (1985). *The Musical Mind: The Cognitive Psychology of Music*. Oxford: OUP.
- Smith, A.B. et al. (2008) A longitudinal study of speech timing in young children later found to have reading disability. *Journal of Speech, Language and Hearing Research*. 51, 1300–1314
- Snyder, J.S., & Krumhansl, C.L. (2001). Tapping to ragtime: Cues to pulse finding. *Music Perception*, 18, 455-489.
- Spencer, H. (1858). *Essays, Scientific, Political and Speculative* (Vol. 1). London: Williams and Norgate. [available at <http://www.gutenberg.net>]
- Stainsby, T; Cross, I. (2009). “The Perception of Pitch.” In S. Hallam, I. Cross, & M. Thaut (Eds.), *The Oxford handbook of music psychology* (47-58). New York: Oxford University Press.
- Stanovich, K. E. (1992). Speculation on the causes and consequences of individual differences in early reading acquisition. In P.B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition*. 1-34.
- Standley, J. M. (2003). *Music therapy with premature infants*. Silver Spring, MD: American Music Therapy Association.
- Starr and Taggart 2004. *Ecology and Behavior from Biology: The Unity and Diversity of Life* 10th edition. Thompson publishers
- Strait, D. L., Kraus, N., Parbery-Clark, A., and Ashley, R. (2010). Musical experience shapes top-down auditory mechanisms: evidence from masking and auditory attention performance. *Hearing Research* 261, 22-29.
- Strait, D. L; Hornickel, J. Kraus, N. (2011) Subcortical processing of speech regularities underlies reading and music aptitude in children. *Behavioural and Brain Functions*, 7: 44
- Strait DL, Chan K, Ashley R, Kraus, N. (2012), Specialization among the specialized: auditory brainstem function is tuned in to timbre. *Cortex*. 48: 360-362.
- Styns, F., van Noorden, L., Moelants, D., & Leman, M. (2007). Walking on music. *Human Movement Science*, 26(5), 769-785.

- Swanwick, K. & Tillman, J. (1986) The sequence of musical development: a study of children's composition, *British Journal of Music Education* 3, 305–339.
- Swanwick, K. (1999). *Teaching Music Musically* (London and New York, Routledge).
- Swanwick, K. & Franca, C.C. (1999) Composing, performing and audience-listening as indicators of musical understanding , *British Journal of Music Education*, 16, 3–17.
- Tallal, P., Miller, S., & Fitch, R. H. (1993). Neurobiological basis of speech: A case for the preminence of temporal processing. In P. Tallal, A. M. Galaburda, R. R. Llinas, & C. von Euler (Eds.), *Temporal information processing in the nervous system: Special reference to dyslexia and dysphasia* (682), 27–47). New York: New York Academy of Sciences.
- Tallal, P., Miller, S. L., Jenkins, W. M., & Merzenich, M. M. (1997). The role of temporal processing in developmental language-based learning disorders: Research and clinical implications. In B. A. Blachman, & B. A. Blachman Eds.), *Foundations of reading acquisition and dyslexia: Implications for early intervention*, 49-66. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
- Tallal, P. (2004) Improving language and literacy is a matter of time. *Nature Reviews Neuroscience* 5, 721-728.
- Tallal, P., & Gaab, N. (2006). Dynamic auditory processing, musical experience and language development. *Trends in Neurosciences*, 29(7), 382-390.
- Taub, G. E., McGrew, K.S, Keith, T.Z, (2007) Improvements in interval time tracking and effects on reading achievement, *Psychology in Schools* (44) 849-863.
- Teachout, D. J. (n.d.). The impact of music education on a child's growth and development. <http://skylinekids.com/documents/GrowthDevelopment.pdf>
- Thaut, M.H. (2005). *Rhythm, music and the brain*. New York and London: Routledge.
- Thomson, J.M, and Goswami, U. (2008). Rhythmic Processing in Children with Developmental Dyslexia: Auditory and Motor Rhythms link to Reading and Spelling. *Journal of Physiology-Paris*, 102, 120-129.
- Tillman, B. & Bigand. E. (1996) Does Formal Musical Structure Affect Perception of Musical Expressiveness? *Psychology of Music* 24 (1) 3-17.

- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, 28, 675–691.
- Torgeson, J. K., & Burgess, S. R. (1998). Consistency of reading-related phonological processes throughout early childhood: *Evidence from longitudinal-correlational and instructional studies*. In Metsala, J. L., & Ehri, L. C. (Eds). Word recognition in beginning literacy. 161-188.
- Torgeson, J. K. (2002). The prevention of reading difficulties. *Journal of School Psychology*, 40(1), 7–26.
- Trainor, L.J., Clark, E.D., Huntley, A. & Adams, B.A. (1997). The acoustic basis of preferences for infant directed singing. *Infant Behavior and Development*, 20, 383-396.
- Trainor, L. J., Desjardins, R. N., and Rockel, C. (1999). A comparison of contour and interval processing in musicians and nonmusicians using event-related potentials. *Australian Journal of Psychology* 51, 147-153.
- Trehub, S. (2003) The Developmental Origins of Musicality. *Nature Neuroscience* 6 (7), 669-673
- Trehub, S. (2006). Musical Predispositions in Infancy. *Annals of the New York Academy of Sciences*, 930,1 -16.
- Trehub, S.E., Trainor, L.J. & Unyk, A.M. (1993). Music and speech processing in the first year of life. In: H.W. Reese (Ed.). *Advances in Child Development and Behavior* 24. New York: Academic Press, 1-35.
- Trehub, S. E., G. Schellenberg & D. Hill. (1997). The origins of music perception and cognition: a developmental perspective. In Deliège, I. and Sloboda, J. A., (Eds.) *Perception and cognition of music*, 103-128. The Psychology Press. Hove.
- Trehub, S., & Hannon, E. (2006). Infant music perception: domain-general or domain specific mechanisms? *Cognition*, 100, 73-99.
- Treiman, R. (1992). The role of intra-syllabic units in learning to read and spell. In P. B.Gough, L. C. Ehri, and R. Treiman (Eds.). *Reading Acquisition*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Treiman, R. & Zukowski, A. (1991). Levels of phonological awareness. In S. A. Brady & D. P.Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* 67–83 Hillsdale, NJ: Erlbaum.

- Trevarthen, C. 1999. Musicality and the intrinsic motive pulse: evidence from human psychobiology and infant communication. *Musicae Scientiae, Special Issue*. 155-215.
- Van Kleeck, A & Schuele, C.M. (1987). Precursors to Literacy: Normal Development. *Topics in Language Disorders* 7,13 -31.
- Vaughn, M. (1981) Intercultural studies in children's natural singing pitch and walking tempo. *Bulletin of the Council for Research in Music Education*, 66-67 96-101
- Verney, J.P. (1991). The integrated instrumental Teacher: Learning to play through performance, listening and composition. *British Journal of Music Education* , 8 (3), 245-269.
- Vloedgraven, J. M., & Verhoeven, L. (2007). Screening of phonological awareness in the early elementary grades: An IRT approach. *Annals of Dyslexia*, 57(1), 33–50.
- Vloedgraven, J. M. T., & Verhoeven, L. (2008). The nature of phonological Awareness throughout the elementary grades: An item response theory perspective. *Learning and Individual Differences*.
- Vos, J. & Rasch, R.A. (1981). The perceptual onset of musical tones. *Perception and Psychophysics*, 29, 323-335.
- Wagner, R.K. & Torgesen, J.K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin* 101 (2), 192-212.
- Wagner, R., Torgesen, J., Laughon, P., Simmons, K., & Rashotte, C. (1993). Development of young reader's phonological processing abilities: New evidence in bi-directional causality from a latent variable.
- Wallace, W., & Rubin, D. C. (1988). "The Wreck of the Old 97". In U. Niesser & E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to the study of memory*. (283-310). Cambridge: Cambridge University Press.
- Wallace, W. T. (1994). Memory for music: Effect of melody on recall of text. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 20 (6), 1471-1485.

- Walters, D. (1983). The relationship between personal tempo in primary aged children and their ability to synchronise to movement with music. *Bulletin of the Council for Research in Music Education*, 88, 85-89.
- Walton, P. D. (1995). Rhyming ability, phoneme identity, letter–sound knowledge, and the use of orthographic analogy by pre-readers, *Journal of Educational Psychology*, 87 (4), 587-597.
- Walton P.D. (2007). Using children’s songs and rhymes to teach phonological skills and beginning readings (*Conference address - Language and Music as cognitive systems*) Cambridge UK.
- Walton, P. (2010) Using Songs and Movement to Teach Reading to Aboriginal Children. Canadian Council For Learning.
- Walton, P. D., Walton, L. D., & Felton, K. (2001). Teaching rime analogy or letter recoding reading strategies to prereaders: Effects on prereading skills and word reading. *Journal of Educational Psychology*, 93, 160-180.
- Walton, P. D., Thorneloe, S., Bowden, M. E., & Angus, M. (2001). Evaluation of a rime-based reading program with Shuswap and Heiltsuk First Nations prereaders. *Reading and Writing*, 14, 229-264.
- Walton, P. D. & Walton, L. M. (2002). Beginning reading by teaching in rime analogy: Effects on phonological skills, letter–sound knowledge, working memory and word-reading strategies. *Scientific Studies of Reading*, 6, 79-115.
- Warrener, J. T. (1985). Learning theory to musical development: Piaget and beyond. *Music Educators Journal*, 72(3), 22–27.
- Wechsler Preschool and Primary Scale of Intelligence. (1991) Revised UK edition.
- Welch. G.F., Sergeant, D.C. and White, P. (1996). The singing competences of five – year-old developing singers. *Bulletin of the Council of Research in Music Education*, 127, 155-162.
- Welch. G.F. (2001). The Misunderstanding of Music. *The Institute of Education*. University of London.
- Welch, G.F (2005). Singing as communication. In D. Miell, R. MacDonald, & D. Hargreaves (Eds.), *Musical Communication* 239–259. Oxford: OUP.
- Weikart, P.S. (2000). *Round the circle: Key experiences in movement for young children*. Ypsilanti, MI: High/Scope Press.

- Wendrich, K. A. (1981). Pitch imitation in infancy and early childhood: Observations and implications. *Dissertation Abstracts International*, 41, 019A. (University Microfilms No. 81-11,923)
- Wermke, & Mende, W. (2011). From Emotion to Notion. The Importance of Melody. In J. Decety, & J.T. Cacioppo .*The Handbook of Social Neuroscience*. New York: Oxford University Press, 2011.
- Whitehurst, G. J., & Lonigan, C. J. (2001). Emergent literacy: Development from prereaders to readers. In S. B Neuman & D. K. Dickinson (Eds.), *Handbook of Early Literacy Research*, 11-29. New York: Guilford Press.
- Winkler, I., Haden, G. P., Ladinig, O., Sziller, I., & Honing, H. (2009). Newborn infants detect the beat in music. *Proceedings of the National Academy of Sciences of the United States of America*, 106(7), 2468–2471.
- Wolff, P.H., Michel, G.F, Ovrut, M, and Drake, C. (1990). Rating and timing precision of motor coordination in developmental dyslexia. *Developmental Psychology*, 26(3): 349-359
- Wolff, P.H. (2002). Timing precision and rhythm in developmental dyslexia. *Reading and Writing: An interdisciplinary Journal* 15, 179-206.
- Wong, P. C. M., Skoe, E. Russo, N. M., Dees, T. & Kraus, N. (2007). Musical experience shapes human brainstem encoding of linguistic pitch patterns. *Nature Neuroscience*, 10 (4), 420–422.
- Wood, C. & Terrell, C. (1998). Poor readers' ability to detect speech rhythm and perceive rapid speech. *British Journal of Developmental Psychology*, 16(3), 397–413.
- Wood, C. (1999). The contribution of analogical problem solving and phonemic awareness to children's ability to make orthographic analogies when reading *Educational Psychology* 19 (3) 277–286.
- Woodrow, H. (1932). The effect of rate of sequence upon the accuracy of synchronization. *Journal of Experimental Psychology*, 15, 357–379.
- Wyse, D., & Goswami, U. (2008). Synthetic phonics and the teaching of reading, *British Educational Research Journal*, 34 (6), 691-710
- Zar, J.H. (1999). *Biostatistical Analysis*. 4th edition. Prentice Hill.
- Zatorre, R.J., Chen, J.L., and Penhune, V.B. (2007) When the brain plays music. Auditory-motor interactions in music perception and production. *Nature Reviews Neuroscience*, 8, 547-558

- Zenatti, A. (1976). Influence de quelques variables socio-culturelles sur le development musical de l'enfant. *Psychologie Francaise*, 21, 185-190.
- Zentner, M., & Eerola, T. (2010). Rhythmic engagement with music in infancy. *Proceedings of the NationalAcademy of Sciences of the United States of America*, 107, 5768–5773.
- Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled read-ing across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, 131(1), 3–29.
- Zimmerman, M.P. (1984). The relevance of Piagetian theory for music education. *International Journal of Music Education*, 3, 31-34.
- Zimmerman, M. P. (1986). Music development in middle childhood: A summary of selected research studies. *Bulletin of the Council for Research in Music Education*, 86, 18–35.